NEW MEXICO ENVIRONMENT DEPARTMENT

Hazardous Waste Bureau
Ground Water Quality Bureau
and
Voluntary Remediation Program

TECHNICAL BACKGROUND DOCUMENT FOR DEVELOPMENT OF SOIL SCREENING LEVELS
REVISION 2.0

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Volume 1

TIER 1: SOIL SCREENING GUIDANCE TECHNICAL BACKGROUND DOCUMENT

Table of Contents

VOLUME 1 TIER 1: SOIL SCREENING GUIDANCE TECHNICAL BACKGROUND DOCUMENT

1. Introduction 1
1.1 Organization of the Document 1
1.2 Scope of the Soil Screening Guidance 2
1.2.1 Exposure Pathways 3
1.2.2 Exposure Assumptions 3
1.2.3 Target Risk and Hazard 4
1.2.4 SSL Model Assumptions 4

2. Development of Pathway Specific Soil Screening Levels 5
2.1 Human Health Basis 5
2.1.1 Additive Risk 5
2.1.2 Acute Exposures 6
2.1.3 Route-to-Route Extrapolation 6
2.1.4 Direct Ingestion 7
2.1.5 Dermal Absorption 7
2.1.6 Inhalation of Volatiles and Fugitive Dusts 7
2.2 Residential Land Uses 8
2.2.1 Residential Receptors 9
2.3 Non-residential land uses 12
2.3.1 Commercial/Industrial Worker 13
2.3.2 Construction Worker 15
2.3.3 Alternative Evaluation for Lead 17
2.4 Site Assessment and Characterization 17
2.4.1 Development of Data Quality Objectives 18
2.4.2 Identification of COPCs 18
2.4.3 Development of a Preliminary Conceptual Site Model 18
2.4.4 Compare COPC Maximum Concentrations With SSLs 19

3. Chemical-Specific and Physical-Chemical Parameters 19
3.1 Volatilization Factor 19
3.2 Soil Saturation Limit 20
3.3 Particulate Emission Factor 21
3.4 Physical-Chemical Parameters 23
3.4.1 Solubility, Henry's Law Constant, and K_{ow} 23
3.4.2 Soil Organic Carbon/Water Partition Coefficients (K_{oc}) 24
3.4.3 Soil/Water Partition Coefficients (K_d) 24

4. Migration of Contaminants to Groundwater 26
4.1 Overview of the SSL Model Approach 26
4.2 Model Assumptions 27
4.3 Soil Water Partition Equation 27
4.4 Dilution Attenuation Factor 28
4.5 Limitations on the Use of the Dilution Attenuation Factor 30
4.6 Generic SSLs for Protection of Groundwater 31

4.7 Development of Site Specific SSLs for Protection of Groundwater 31
4.8 Detailed Model Analysis for SSL Development 34
4.9 Summary of the Migration to Groundwater Pathway SSLs.. 34

5. Use of the SSLs 35

Appendix A:
Table A-1: NMED Soil Screening Levels
Table A-2: Default Exposure factors
Appendix B
Table B-1: Physical-Chemical Properties
Appendix C
Table C-1: Human Health Benchmarks Used for calculating SSLs

Table of Contents, Cont.

VOLUME 2 TIER 1: SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT PHASE I SCOPING ASSESSMENT

1. Introduction 1

2. Scoping Assessment 2
   - 2.1 Compile and Assess Basic Site Information 2
   - 2.2 Site Visit 3
   - 2.3 Identify Contaminants of Potential Ecological Concern 4
   - 2.4 Developing the Preliminary Conceptual Site Exposure Model 4
   - 2.5 Assembling the Scoping Assessment Report 6

3. Site Exclusion Criteria 9

4. Technical Decision Point: Is Ecological Risk Suspected? 9

Attachment A: Screening-Level Ecological Risk Assessment Scoping Assessment: Site Assessment Checklist
Table 1: Examples of Sensitive Environments

Attachment B: Ecological Site Exclusion Checklist and Decision Tree

LIST OF ACRONYMS

ASTDR	Agency for Toxic Substances and Disease Registry
CMTP	Composite Model for Leachate Migration with Transformation Products
COPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DQO	Data Quality Objectives
EPA/ORD	Environmental Protection Agency Office of Research and Development
GWQB	Groundwater Quality Bureau
HEAST	Health Effects Assessment Summary Tables
HWB	Hazardous Waste Bureau
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
MCLG	Nonzero Maximum Contaminant Level
MRL	Minimum Risk Level
NAPL	Non-aqueous Phase Liquid
NCEA	National Center for Environmental Assessment
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NRCS	National Resource Conservation Service
PEF	Particulate Emission Factor
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
SCEM	Site Conceptual Exposure Model
SF	Slope Factor
SSG	Soil Screening Guidance
SSL	Soil Screening Level
SVOC	Semi-volatile Organic Compound
UCL	Upper Confidence Limit
URF	Unit Risk Factor
USEPA	United States Environmental Protection Agency
VF	Volatilization Factor
VOC	Volatile Organic Compound
WQCC	Water Quality Control Commission

1. Introduction

The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) and the Ground Water Quality Bureau (GWQB) have developed this soil screening guidance (SSG) for internal department use for corrective action programs. The SSG discusses the methodology used to derive chemical-specific soil screening levels (SSLs). In addition, guidance is provided to assist in identifying and evaluating appropriate exposure pathways and receptors. Finally, this document provides generic SSLs for chemicals commonly found at contaminated sites based on default exposure parameters under residential and non-residential land-use scenarios.

The SSG provides site managers with a framework for developing and applying the SSLs, and is likely to be most useful for determining whether areas or entire sites are contaminated to an extent that warrants further investigation. It is intended to assist and streamline the site investigation and corrective action process by focusing resources on those sites or areas that pose the greatest risk to human health and the environment. Implementation of the methodologies outlined within this SSG may significantly reduce the time necessary to complete site investigations and cleanup actions at certain sites, as well as improve the consistency of these investigations.

Between various sites there can exist a wide spectrum of contaminant types and concentrations. The level of concern associated with those concentrations depends on several factors, including the likelihood of exposure to levels of potential concern to human health or to ecological receptors. At one end of the spectrum are levels that clearly warrant a response action; at the other end are levels that are below regulatory concern. Appropriate cleanup goals for a site may fall anywhere within this range depending on site-specific conditions. It is important to note that SSLs do not in themselves represent cleanup standards, and the SSLs alone do not trigger the need for a response action or define "unacceptable" levels of contamination in soil. Screening levels such as SSLs identify the lower end of this spectrum – levels below which there is generally no need for further concern—provided the conditions associated with the development of the SSLs are consistent.

1.1 Organization of the Document

The NMED SSG is organized into five major sections with supporting appendices. The remainder of Section 1 addresses the purpose of the NMED SSLs and outlines the scope of the document. Section 2 outlines the receptors, exposure pathways, and exposure assumptions used in calculating the NMED SSLs. It also discusses the risk levels on which the SSLs are predicated and presents the SSL model assumptions. Finally, Section 2 discusses site assessment/characterization activities that should be completed prior to comparing site contaminant concentrations with SSLs. These activities include development of data quality objectives, conducting site sampling, preparation of a preliminary conceptual site model (CSM), and identification of contaminants of potential concern (COPCs). Section 3 provides a detailed description of the process used to develop pathway-specific SSLs. Included in this section is a discussion of the human health basis for the SSLs, additive risk, and acute exposures. Additional topics discussed in Section 3 include chemical specific parameters used to develop the SSLs and calculating volatilization factors, particulate emission factors and soil saturation limits. Section 4 presents methodologies for assessing the potential for migration of contaminants to groundwater from contaminated soil in concert with generic and site-specific leaching models. Finally, Section 5 addresses special use considerations for addressing contaminant concentrations in soil and notes specific problems that can arise when applying the SSLs to specific sites. Generic SSLs for contaminants that have Water Quality Control Commission (WQCC) Standards for ground water in the State of New Mexico are presented in Table A-1 of Appendix A. In addition, Table A-1 also includes additional compounds, which are some of the Resource Conservation and Recovery Act (RCRA) regulated constituents. Table A-2 of Appendix A presents the default exposure factor values used in the generation of the NMED SSLs. Physical-chemical values in the calculation of the SSLs are presented in Table B-1 of Appendix B. Toxicity criteria are presented in Table C-1 of Appendix C.

1.2 Scope of the Soil Screening Guidance

The SSG incorporates readily obtainable site data and utilizes methods from various United States Environmental Protection Agency (US EPA) risk assessment guidance and derives site-specific screening levels for selected contaminants and exposure pathways. Key attributes of the SSG include default values for generic SSLs where site-specific information is unavailable, and the identification of parameters for which site-specific information is needed for the development of site-specific SSLs. The goal of the SSG is to provide a consistent approach for developing site-specific SSLs for evaluating facilities under the auspices of the corrective action process within NMED.

The NMED SSLs are generally based on a 1E-05 target risk for carcinogens, or a hazard quotient of 1 for noncarcinogens. In instances where an individual contaminant has the capacity to elicit both types of responses, the SSLs preferentially report the screening value representative of the lowest (most stringent) contaminant concentration in environmental media. SSLs for migration to groundwater are based on (in order of preference): State of New Mexico WQCC standards (NMAC 2002), US EPA Region 9 Preliminary Remediation Goals (PRGs) for tap water (USEPA 2002a), maximum contaminant levels (MCL), and nonzero maximum contaminant level goals (MCLG) (USEPA 2003b). As such, the NMED SSLs serve as a generic benchmark for screening level comparisons of contaminant concentrations in soil. NMED anticipates that the SSLs will be used as a tool to facilitate prompt identification of those contaminants and areas that represent the greatest risks to human health and the environment. While concentrations above the NMED SSLs presented in this document do not automatically designate a site as "contaminated" or trigger the need for a response action, detected concentrations in site soils exceeding screening levels suggest that further evaluation is appropriate. Further evaluation may include additional sampling to further characterize the nature and extent of contamination, consideration of background levels, reevaluation of COPCs or associated risk and hazard using site-specific parameters, and/or a reassessment of the assumptions associated with the generic SSLs (e.g., appropriateness of route-to-route extrapolations, use of chronic toxicity values to evaluate childhood and construction-worker exposures).

1.2.1 Exposure Pathways

A complete exposure pathway consists of (1) a source, (2) a mechanism of contaminant release, (3) a receiving or contact medium, (4) a potential receptor population, and (5) an exposure route. All five elements must be present for the exposure pathway to be considered complete.

SSLs have been developed for use in evaluating three discrete exposure scenarios representing a variety of potential land uses: residential, commercial/industrial, and construction. The SSG presents lists of potential pathways for each scenario, though these lists are not intended to be exhaustive. Instead, each list represents a set of typical exposure pathways likely to account for the majority of exposure to contaminants in soil at a given site. These include:

- Direct (or incidental) ingestion of soil
- Dermal contact with soil
- Inhalation of volatiles and fugitive dusts from contaminated soil
- Migration of chemicals through soil to an underlying potable aquifer or water-bearing unit

Under some site-specific situations, additional complete exposure pathways may be identified. In these cases, a site-specific evaluation of risk is warranted in which additional exposure pathways can be considered. If other land uses and exposure scenarios are determined to be more appropriate for a site (e.g., Native American land use), the exposure pathways addressed in this document should be modified accordingly or a site-specific risk assessment should be conducted. Early identification of the need for additional information is important because it facilitates development of a defensible sampling and analysis strategy.

The exposure pathways evaluated, by land-use scenario, are presented in Table 1-1.

Table 1-1

Exposure Pathways Evaluated in Soil Screening Guidance

Potential Exposure Pathway	Residential	Commercial/industrial	Construction
Direct ingestion	✓	✓	✓
Dermal contact	✓	✓	✓
Inhalation of volatiles outdoors	✓	✓	✓
Inhalation of fugitive dusts outdoors	✓	✓	✓
Inhalation of volatiles indoors	✓		

1.2.2 Exposure Assumptions

SSLs represent risk-based concentrations in soil derived from equations combining exposure assumptions with toxicity criteria developed by US EPA (US EPA 2003a and 1997a) and the National Center for Environmental Assessment (NCEA) (USEPA 2003c). The models and assumptions used were developed to be consistent with the Superfund concept of "reasonable maximum exposure" (US EPA 1989). This is intended to provide an upper-bound estimate of chronic exposure by combining both average and conservative (i.e., 90^{th} to 95^{th} percentile) values in the calculations. The default intake and duration assumptions presented here are intended to be protective of all potentially exposed populations for each land use consideration. Exposure point concentrations in soil should reflect either directly measured or estimated values using fate and transport models. An average concentration is typically used where the focus is on estimating long-term, chronic exposures and there are sufficient site data to allow for an accurate estimation of the mean. Where the potential for acute toxicity may be of concern, estimates based on the maximum exposure may be more appropriate.

The resulting estimate of exposure is then compared with chemical-specific toxicity criteria. To calculate the SSLs, the exposure equations and pathway models are rearranged to backcalculate an "acceptable level" of a contaminant in soil corresponding to a specific level of target risk or hazard.

1.2.3 Target Risk and Hazard

Target risk and hazard levels for human health are risk management-based criteria for carcinogenic and non-carcinogenic responses, respectively, to determine (1) whether site-related contamination poses an unacceptable risk to human health and requires corrective action or (2) whether implemented corrective action(s) sufficiently protects human health. If an estimated risk or hazard falls within the target range, the risk manager may conclude that a site does not pose an unacceptable risk. This decision should take into account the degree of inherent conservatism or level of uncertainty associated with the site-specific estimates of risk and hazard. An estimated risk that exceeds these targets, however, does not necessarily indicate that the current conditions are not safe or that they present an unacceptable risk. Rather, a site risk calculation that exceeds a target value may simply indicate the need for further evaluation or refinement of the exposure model.

For cumulative exposure via the ingestion, inhalation, and dermal pathways, toxicity criteria are used to calculate an acceptable level of contamination in soil. SSLs are based on a carcinogenic risk level of one-in-one-hundred thousand (1E-05) and a non-carcinogenic hazard quotient of 1. A carcinogenic risk level is defined as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. The non-carcinogenic hazard quotient assumes that there is a level of exposure below which it is unlikely for even sensitive populations to experience adverse health effects.

1.2.4 SSL Model Assumptions

The models used to calculate inhalation exposure and protection of groundwater based on potential migration of contaminants in soil are intended to be utilized at an early stage in the site investigation process when information regarding the site may be limited. For this reason, the models incorporate a number of simplifying assumptions. For instance, the models assume an infinite contaminant source, i.e. a constant concentration is maintained for the duration of the exposure period. Although this is a highly conservative assumption, finite source models require accurate data regarding source size and volume. Such data are unlikely to be available from limited sampling efforts. The models also assume that contamination is homogeneous throughout the source and that no biological or chemical degradation occurs. Where sufficient site-specific data are available, more-detailed finite-source models may be used in place of the default assumptions presented in this SSG.

2. Development of Pathway Specific Soil Screening Levels

The following sections present the technical basis and limitations used to calculate SSLs for residential, commercial/industrial, and construction land use scenarios. The equations used to evaluate inhalation and migration to groundwater include a number of easily obtainable site-specific input parameters. Where site-specific data are not available, conservative default values are presented. The equations used are presented in Sections 2.2 and 2.3. Generic SSLs calculated for 206 chemicals, using these default values, are presented in Table A-1 of Appendix A.

2.1 Human Health Basis

The toxicity criteria used for calculating the SSLs are presented in Table C-1 of Appendix C. The primary sources for the human health benchmarks are US EPA's Integrated Risk Information System (IRIS) (US EPA 2003a), US EPA's NCEA (USEPA 2003c), and the Health Effects Assessment Summary Tables (HEAST) (US EPA 1997a). Additional sources include the minimal risk levels (MRLs) developed by the Agency for Toxic Substances and Disease Registry (ATSDR). For soil ingestion, inhalation of volatile organic compounds (VOCs) and fugitive dusts, and dermal contact, the NMED SSLs correspond to a 1E-05 level for carcinogens and/or a hazard quotient of 1 for noncarcinogens, whichever is lower (i.e., more protective).

2.1.1 Additive Risk

It is important to note that no consideration is provided in the calculation of individual NMED SSLs for additive risk when exposures to multiple chemicals occur. The SSG addresses this issue in Section 5. Because the NMED SSLs for carcinogenic effects correspond to a 1E-05 risk level individually, exposure to multiple contaminants may result in a cumulative site risk that is above the anticipated risk management range. While carcinogenic risks of multiple chemicals are simply added together, the issue of additive hazard is more complex for noncarcinogens because of the theory that a threshold exists for noncarcinogenic effects. This threshold is defined as the level below which adverse effects are not expected to occur, and represents the basis for the reference dose (RfD) and reference concentration (RfC). Since adverse effects are not expected to occur at the RfD or RfC and the SSLs are derived by setting the potential exposure dose to the RfD or RfC, the SSLs do not address the risk of exposure to multiple chemicals at levels where the individual chemicals alone would not be expected to cause any adverse effects. In such cases, the SSLs may not provide an accurate indicator for the likelihood of harmful effects. However, noncarcinogenic effects should only be considered additive for those chemicals with the same toxic endpoint and/or mechanism of action. The sources provided in Section 2.1 should be consulted to determine the endpoint and/or target organ system prior to attempting to evaluate the additive health effects resulting from simultaneous exposure to multiple contaminants.

Additivity of the SSLs is further complicated by the fact that not all of the SSLs are based on toxicity. SSLs for certain volatile chemicals are determined based on a ceiling limit concentration termed the soil saturation limit (and denoted as C_{sat}) above which these chemicals may occur as nonaqueous phase liquids (NAPLs) in soil. This is discussed further in Section 3.2. Further, for certain inorganic and semivolatile organic compounds (SVOCs) that exhibit relatively low toxicity, a non risk-based maximum concentration of 10^5 mg/kg is given when the risk-based SSL exceeds that level. These are noted as "max" in the tables.

2.1.2 Acute Exposures

The exposure assumptions used to develop the SSLs are based on a chronic exposure scenario and do not account for situations where high-level exposures may result in acute toxic effects. Such situations may arise when contaminant concentrations are very high, or may result from specific site-related conditions and/or behavioral patterns (i.e., pica behavior in children). Such exposures may be of concern for those contaminants that primarily exhibit acute health effects. Toxicological information regarding cyanide and phenol indicate that acute effects may be of concern for children exhibiting pica behavior. Pica is typically described as a compulsive craving to ingest non-food items (such as clay or paint). Although it can be exhibited by adults as well, it is typically of greatest concern in children because they often exhibit behavior (e.g., outdoor play activities and greater hand-to-mouth contact) that results in greater exposure to soil than for a typical adult. In addition, children also have a lower overall body weight relative to the predicted intake.

2.1.3 Route-to-Route Extrapolation

As of January 1991, IRIS and NCEA databases no longer present RfDs or SFs for the inhalation route. These criteria have been replaced with RfCs for noncarcinogenic effects and unit risk factors (URFs) for carcinogenic effects. However, for the purposes of estimating risk and calculating risk-based concentrations, inhalation reference doses (RfD_i) and inhalation slope factors (SF_i) are preferred. Route-to-route extrapolations were also frequently used when there were no toxicity values available for a given route of exposure. However, route extrapolations were not performed for inorganics due to portal of entry effects and known differences in absorption efficiency between the oral and dermal routes of exposure. To calculate an RfD_i from an RfC, the following equation and assumptions may be used for most chemicals:

$$RfD_i \ \frac{mg}{(kg - day)} = RfC\,(mg / m^3) \times \frac{20m^3}{day} \times \frac{1}{70kg}$$

The SF_i was calculated from the URF using the following equation and assumptions:

$$SF_i \ \frac{(kg - day)}{(mg)} = URF\left(m^3/mg\right) \times \frac{day}{20m^3} \times 70kg \times \frac{10^3\ ug}{mg}$$

An additional route extrapolation is the use of oral toxicity values for evaluating dermal exposures. Because no toxicity data are presently available for evaluating dermal exposure to contaminants, US EPA has developed a methodology for use in dermal assessments. Most oral RfDs and cancer slope factors are based on an administered dose while dermal equations estimate an absorbed dose. Gastrointestinal and pulmonary absorption of many chemicals is typically much greater than absorption through intact skin. Thus, for evaluating the effects of dermal exposure to contaminants in soil, the oral toxicity value should be adjusted from an administered dose to an absorbed dose by accounting for the absorption efficiency of the chemical. Assuming 100 percent absorption via the oral exposure route may result in an overestimation of the absorbed dose, resulting in an overestimation of the dose at the site of toxic injury and underestimating the actual potency of the chemical to exert an observed effect. The magnitude of the underestimation is inversely proportional to the true oral absorption of the compound. Based on the current guidance (US EPA 2000a), the only chemical for which an adjustment is recommended is cadmium. An oral absorption efficiency of five (5) percent is assumed for cadmium, which leads to an estimated dermal reference dose (RfD_d) of 2.5E-05 mg/kg-day.

2.1.4 Direct Ingestion

Exposure to contaminants through incidental ingestion of soil can result from the inadvertent consumption of soils adhering to the hands, food items, or objects that are placed into the mouth. It can also result from swallowing dust particles that have been inhaled and deposited in the mouth and subsequently swallowed. Commercial/industrial and construction workers and residential receptors may inadvertently ingest soil that adheres to their hands while involved in work- or recreation-related activities. Calculation of SSLs for direct ingestion are based on the methodology presented in US EPA's *Risk Assessment Guidance for Superfund (RAGS): Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim* (US EPA 1991 2001), *Soil Screening Guidance: Technical Background Document* (US EPA 1996a), and *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (US EPA 2001a).

2.1.5 Dermal Absorption

Exposure to soil contaminants may result from dermal contact with contaminated soil and the subsequent absorption of contaminants through the skin. Contact with soil is most likely to occur as a result of digging, gardening, landscaping, or outdoor recreation activities. Excavation activities may also be a potential source of exposure to contaminants, particularly for construction workers. Calculation of the screening levels for ingestion of soil under the residential exposure scenario is based on the methodology presented in EPA's *Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim* (1991), and *Soil Screening Guidance: Technical Background Document* (US EPA 1996a). The suggested default input values used to develop the NMED SSLs are consistent with EPA's interim *RAGS, Part E, Supplemental Guidance for Dermal Risk Assessment* (US EPA 2001).

2.1.6 Inhalation of Volatiles and Fugitive Dusts

EPA toxicity data indicate that risks from exposure to some chemicals via the inhalation pathway far outweigh the risk via ingestion or dermal contact; therefore, the NMED SSLs have been designed to address inhalation of volatiles and fugitive dusts. To address the soil/sediment-to-air pathways, the SSL calculations incorporate volatilization factors (VF) for volatile contaminants and particulate emission factors (PEF) for nonvolatile contaminants. The SSLs follow the procedures for evaluating inhalation of VOCs and fugitive dust particles presented in EPA's *Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim* (US EPA 1991), *Soil Screening Guidance: Technical Background Document* (US EPA 1996a), *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (US EPA 1998a), and *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (US EPA 2001a).

VOCs may adhere to soil particles or be present in interstitial air spaces in soil, and may volatilize into ambient air. This pathway may be particularly significant if the VOC emissions are concentrated in indoor spaces of onsite buildings. For the purpose of calculating the NMED SSLs, VOCs are considered those chemicals having a Henry's Law constant greater than 1×10^{-5} atm-m^3/mole-^oK and a molecular weight less than 200 g/mole.

Inhalation of contaminants via inhalation of fugitive dusts is assessed using a PEF that relates the contaminant concentration in soil/sediment with the concentration of respirable particles in the air due to fugitive dust emissions. It is important to note that the PEF used to address residential and commercial/industrial exposures evaluates only windborne dust emissions and does not consider emissions from traffic or other forms of mechanical disturbance which could lead to a greater level of exposure. The PEF used to address construction worker exposures evaluates windborne dust emissions and emissions from vehicle traffic associated with construction activities. Therefore, the fugitive dust pathway should be considered carefully when developing the CSM at sites where receptors may be exposed to fugitive dusts by other mechanisms. The development of the PEF for both residential and non-residential land uses is discussed further in Section 3.3.

2.2 RESIDENTIAL LAND USES

Residential exposures are assessed based on child and adult receptors. As discussed below, the child forms the basis for evaluation of noncarcinogenic effects incurred under residential exposures, while carcinogenic responses are modeled based upon age-adjusted values to account for exposures averaged over a lifetime. Under most circumstances, onsite residential receptors are expected to be the most conservative receptor basis for risk assessment purposes due to the assumption that exposure occurs 24 hours a day, 350 days per year, extending over a 30-year exposure duration. Table 2-1 provides a summary of the exposure characteristics and parameters associated with a residential land use receptor.

Table 2-1

Summary of the Residential Land Use Receptors	
Exposure Characteristics	Substantial soil exposure (esp. children) High soil ingestion rate (esp. children) Significant time spent indoors Long-term exposure
Default Exposure Parameters	
Exposure frequency (d/yr)	350
Exposure duration (yr)	6 (child) 24 (adult)
Soil ingestion rate (mg/day)	200 (child) 100 (adult)
Body Weight (kg)	15 (child) 70 (adult)
Skin surface area exposed (cm^2)	2,800 (child) 5,700 (adult)
Skin-soil adherence factor	0.2 (child) 0.07 (adult)
Air inhalation rate (m^3/d)	10 (child) 20 (adult)

2.2.1 Residential Receptors

A residential receptor is assumed to be a long-term receptor occupying a dwelling within the site boundaries and thus is exposed to contaminants 24 hours per day, and is assumed to live at the site for 30 years (representing the 90th percentile of the length of time someone lives in a single location), remaining onsite for 350 days per year. Exposure to soil is expected to occur during home maintenance activities, yard work and landscaping, and outdoor play activities. Contaminant intake is assumed to occur via three exposure pathways – direct ingestion, dermal absorption, and inhalation of volatiles and fugitive dusts. For the residential scenario, both adult and child receptors were evaluated because children often exhibit behavior (e.g., greater hand-to-mouth contact) that can result in greater exposure to soils than those associated with a typical adult. In addition, children also have a lower overall body weight relative to the predicted intake.

Equations 1 and 2 are used to calculate cumulative SSLs for a residential receptor exposed to non-carcinogenic and carcinogenic contaminants via all three exposure pathways. Default exposure parameters are provided for use when site-specific data are not available.

Equation 1
Combined Exposures to Noncarcinogenic Contaminants in Soil
Residential Scenario

$$C = \frac{THQ \times BW_c \times AT_n}{EF_r \times ED_c \left[\left(\frac{1}{RfD_o} \times \frac{IRS_c}{10^6\ mg/kg} \right) + \left(\frac{1}{RfD_o} \times \frac{SA_c \times AF_c \times ABS}{10^6\ mg/kg} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_c}{VF \text{ or } PEF} \right) \right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
THQ	Target hazard quotient	1
BW_c	Body weight, child (kg)	15
AT_n	Averaging time, noncarcinogens (days)	ED x 365day/yr
EF_r	Exposure frequency, resident (day/yr)	350
ED_c	Exposure duration, child (years)	6
IRS_c	Soil ingestion rate, child (mg/day)	200
RfD_o	Oral reference dose (mg/kg-day)	Chemical-specific
SA_c	Dermal surface area, child (cm^2/day)	2,800
AF_c	Soil adherence factor, child (mg/cm^2)	0.2
ABS	Skin absorption factor (unitless)	Chemical-specific
IRA_c	Inhalation rate, child (m^3/day)	10
RfD_I	Inhalation reference dose (mg/kg-day)	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

Equation 2
Combined Exposures to Carcinogenic Contaminants in Soil
Residential Scenario

$$C = \frac{TR \times AT_c}{EF_r \left[\left(\frac{IFS_{adj} \times CSF_o}{10^6 mg/kg} \right) + \left(\frac{SFS_{adj} \times ABS \times CSF_o}{10^6 mg/kg} \right) + \left(\frac{InhF_{adj} \times CSF_i}{VF \text{ or } PEF} \right) \right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
TR	Target cancer risk	1E-05
AT_c	Averaging time, carcinogens (days)	25,550
EF_r	Exposure frequency, resident (day/yr)	350
IFS_{adj}	Age-adjusted soil ingestion factor ([mg-yr]/[kg-day])	114

CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
SFS_{adj}	Age-adjusted dermal factor ([mg-yr]/[kg-day])	361
ABS	Skin absorption factor (unitless)	Chemical-specific
$InhF_{adj}$	Age-adjusted inhalation factor ($[m^3$-yr]/[kg-day])	11
CSF_i	Inhalation cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

Noncarcinogenic contaminants are evaluated based solely on childhood exposures using Equation 1. By combining the higher contaminant intake rates with the lower relative body weight, "childhood only" exposures lead to a lower, or more conservative, risk-based concentration compared to an adult-only exposure. In addition, this approach is considered conservative because it combines the higher 6-year exposure for children with chronic toxicity criteria.

Unlike non-carcinogens, the duration of exposure to carcinogens is averaged over the lifetime of the receptor because of the assumption that cancer may develop even after actual exposure has ceased. As a result, the total dose received is averaged over a lifetime of 70 years. In addition, to be protective of exposures in a residential setting, the carcinogenic exposure parameter values are age-adjusted to account for exposures incurred in children (1-6 years of age) and adults (7-31 years of age). Carcinogenic exposures are age-adjusted to account for the physiological differences between children and adults as well as behavioral differences that result in markedly different relative rates of exposure. Equations 3, 4, and 5 are used to calculate age-adjusted ingestion, dermal and inhalation factors which account for the differences in soil ingestion rate, skin surface area, soil adherence factors, inhalation rate, and body weight for children versus adults. The age-adjusted factors calculated using these equations were used in Equation 2 to develop generic NMED SSLs for carcinogenic effects.

Equation 3
Calculation of Age-Adjusted Ingestion Factor

$$IFS_{adj} = \frac{ED_c \times IRS_c}{BW_c} + \frac{\left(ED_r - ED_c\right) \times IRS_a}{BW_a}$$

Parameter	Definition (units)	Default
IFS_{adj}	Age-adjusted soil ingestion factor for carcinogens [(mg-yr)/(kg-day)]	114
ED_c	Exposure duration, child (years)	6
IRS_c	Soil ingestion rate, child (mg/day)	200
BW_c	Body weight, child (kg)	15
ED_r	Exposure duration, resident (years)	30
IRS_a	Soil ingestion rate, adult (mg/day)	100
BW_a	Body weight, adult (kg)	70

Equation 4
Calculation of Age-Adjusted Dermal Factor

$$SFS_{adj} = \frac{ED_c \times AF_c \times SA_c}{BW_c} + \frac{(ED_r - ED_c) \times AF_a \times SA_a}{BW_a}$$

Parameter	Definition (units)	Default
SFS_{adj}	Age-adjusted dermal factor for carcinogens [(mg-yr)/(kg-day)]	361
ED_c	Exposure duration, child (years)	6
AF_c	Soil adherence factor, child (mg/cm^2)	0.2
SA_c	Dermal surface area, child (cm^2/day)	2,800
BW_c	Body weight, child (kg)	15
ED_r	Exposure duration, resident (years)	30
AF_a	Soil adherence factor, adult (mg/cm^2)	0.07
SA_a	Dermal surface area, adult (cm^2/day)	5,700
BW_a	Body weight, adult (kg)	70

Equation 5
Calculation of Age-Adjusted Inhalation Factor

$$InhF_{adj} = \frac{Ed_c \times IRA_c}{BW_c} + \frac{(ED_r - ED_c) \times IRA_a}{BW_a}$$

Parameter	Definition (units)	Default
$InhF_{adj}$	Age-adjusted inhalation factor for carcinogens [(mg-yr)/(kg-day)]	11
ED_c	Exposure duration, child (years)	6
IRA_c	Inhalation rate, child (m^3/day)	10
BW_c	Body weight, child (kg)	15
ED_r	Exposure duration, resident (years)	30
IRA_a	Inhalation rate, adult (m^3/day)	20
BW_a	Body weight, adult (kg)	70

2.3 NON-RESIDENTIAL LAND USES

Non-residential land uses encompass all commercial and industrial land uses and focus on two very different receptors – a commercial/industrial worker and a construction worker. Unlike those calculated for residential land-uses, NMED SSLs for non-residential land uses are based solely on exposures to adults. Consequently, exposures to carcinogens are not age-adjusted. Due to the wide range of activities and exposure levels a non-residential receptor may be exposed to during various work-related activities, it is important to ensure that the default exposure parameters are representative of site-specific conditions. Table 2-2 provides a summary of the exposure characteristics and parameters for non-residential land use receptors.

Table 2-2

Summary of Non-Residential Land Use Receptors		
Receptor	**Commercial/Industrial Worker**	**Construction Worker**
Exposure Characteristics	Substantial soil exposures High soil ingestion rate Long-term exposure Exposure to surface and shallow subsurface soils Adult-only exposure	Exposed during construction activities only Short-term exposure Very high soil ingestion and dust inhalation rates Exposure to surface and subsurface soils
Default Exposure Parameters		
Exposure frequency (day/yr)	225	250
Exposure duration (yr)	25	1
Soil ingestion rate (mg/day)	100	330
Body Weight (kg)	70	70
Skin surface area exposed (cm^2)	3,300	3,300
Skin-soil adherence factor (mg/ cm^2)	0.2	0.3
Air inhalation rate (m^3/day)	20	20

2.3.1 Commercial/Industrial Worker

The commercial/industrial scenario is considered representative of on-site workers who spend all or most of their workday outdoors. A commercial/industrial worker is assumed to be a long-term receptor exposed during the course of a work day as either (1) a full time employee of a company operating on-site who spends most of the work day conducting maintenance or manual labor activities outdoors or (2) a worker who is assumed to regularly perform grounds-keeping activities as part of his/her daily responsibilities. Exposure to surface and shallow subsurface soils (i.e., at depths of zero to two feet below ground surface) is expected to occur during moderate digging associated with routine maintenance and grounds-keeping activities. A commercial/industrial receptor is expected to be the most highly exposed receptor in the outdoor environment under generic or day-to-day commercial/industrial conditions. Thus, the screening levels for this receptor are expected to be protective of other reasonably anticipated indoor and outdoor workers at a commercial/industrial facility. However, screening levels developed for the commercial/industrial worker may not be protective of a construction worker due to the latter's increased soil contact rate during construction activities. Equations 6 and 7 were used to develop generic SSLs for cumulative exposure to carcinogenic and non-carcinogenic contaminants by all exposure pathways. Default exposure parameters (US EPA 2001) are provided and were used in calculating the NMED SSLs.

Equation 6
Combined Exposures to Carcinogenic Contaminants in Soil
Commercial/Industrial Scenario

$$C = \frac{TR \times BW_a \times AT_c}{EF_{CI} \times ED_{CI}\left[\left(\frac{IRS_{CI} \times CSF_o}{10^6{}_{mg/kg}}\right) + \left(\frac{SA_{CI} \times AF_{CI} \times ABS \times CSF_o}{10^6{}_{mg/kg}}\right) + \left(\frac{IRA_c \times CSF_i}{VF \text{ or } PEF}\right)\right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
TR	Target Risk	1E-05
BW_a	Body weight, adult (kg)	70
AT_c	Averaging time, carcinogens (days)	25,550
EF_{CI}	Exposure frequency, commercial/industrial (day/yr)	225
ED_{CI}	Exposure duration, commercial/industrial (years)	25
IRS_{CI}	Soil ingestion rate, commercial/industrial (mg/day)	100
CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
SA_{CI}	Dermal surface area, commercial/industrial (cm^2/day)	3,300
AF_{CI}	Soil adherence factor, commercial/industrial (mg/cm^2)	0.2
ABS	Skin absorption factor (unitless)	Chemical-specific
IRA_{CI}	Inhalation rate, commercial/industrial (m^3/day)	20
CSF_i	Inhalation cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

Equation 7
Combined Exposures to Noncarcinogenic Contaminants in Soil
Commercial/Industrial Scenario

$$C = \frac{THQ \times BW_a \times AT_n}{EF_{CI} \times ED_{CI}\left[\left(\frac{1}{RfD_o} \times \frac{IRS_{CI}}{10^6\,mg/kg}\right) + \left(\frac{1}{RfD_o} \times \frac{SA_{CI} \times AF_{CI} \times ABS}{10^6\,mg/kg}\right) + \left(\frac{1}{RfD_i} \times \frac{IRA_{CI}}{VF \text{ or } PEF}\right)\right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
THQ	Target hazard quotient	1
BW_a	Body weight, adult (kg)	70
AT_n	Averaging time, noncarcinogens (days)	ED x 365
EF_{CI}	Exposure frequency, commercial/industrial (day/yr)	225
ED_{CI}	Exposure duration, commercial/industrial (years)	25
IRS_{CI}	Soil ingestion rate, commercial/industrial (mg/day)	100
RfD_o	Oral reference dose (mg/kg-day)	Chemical-specific
SA_{CI}	Dermal surface area, commercial/industrial (cm^2/day)	3,300
AF_{CI}	Soil adherence factor, commercial/industrial (mg/cm^2)	0.2
ABS	Skin absorption factor (unitless)	Chemical-specific
IRA_{CI}	Inhalation rate, commercial/industrial (m^3/day)	20
RfD_i	Inhalation reference dose (mg/kg-day)	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

2.3.2 Construction Worker

A construction worker is assumed to be a receptor who is exposed to contaminated soil during the work day for the duration of a single on-site construction project. If multiple construction projects are anticipated, it is assumed that different workers will be employed for each project. The activities for this receptor typically involve substantial exposures to surface and subsurface soils (i.e., at depths of zero to 10 feet below ground surface) during excavation, maintenance and building construction projects (intrusive operations). A construction worker is assumed to be exposed to contaminants via the following pathways: incidental soil ingestion, dermal contact with soil, and inhalation of contaminated outdoor air (volatile and particulate emissions). While a construction worker receptor is assumed to have a higher soil ingestion rate than a commercial/industrial worker due to the type of activities performed during construction projects, the exposure frequency and duration are assumed to be significantly shorter due to the short-term nature of construction projects. However, chronic toxicity information was used when developing screening levels for a construction worker receptor. This approach is significantly more conservative than using sub-chronic toxicity data because it combines the higher soil exposures for construction workers with chronic toxicity criteria. Equations 8 and 9 were used to develop generic SSLs for cumulative exposure to carcinogenic and non-carcinogenic contaminants by all exposure pathways. Default exposure parameters (US EPA 2001) are provided and were used in calculating the NMED SSLs.

Equation 8
Combined Exposures to Carcinogenic Contaminants in Soil
Construction Worker Scenarios

$$C = \frac{THQ \times BW_a \times AT_c}{EF_{CW} \times ED_{CW}\left[\left(\frac{IRS_{CW} \times CSF_o}{10^6\,mg/kg}\right) + \left(\frac{SA_{CW} \times AF_{CW} \times ABS \times CSF_o}{10^6\,mg/kg}\right) + \left(\frac{IRA_{CW} \times CSF_i}{VF\ or\ PEF}\right)\right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
TR	Target Risk	1E-05
AT_c	Averaging time, carcinogens (days)	25,550
EF_{CW}	Exposure frequency, construction worker (day/yr)	250
ED_{CW}	Exposure duration, construction worker (years)	1
IRS_{CW}	Soil ingestion rate, construction worker (mg/day)	330
CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
SA_{CW}	Dermal surface area, construction worker (cm^2/day)	3,300
AF_{CW}	Soil adherence factor, construction worker (mg/cm^2)	0.3
ABS	Skin absorption factor (unitless)	Chemical-specific
IRA_{CW}	Inhalation rate, construction worker (m^3/day)	20
CSF_i	Inhalation cancer slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

Equation 9
Combined Exposures to Noncarcinogenic Contaminants in Soil
Construction Worker Scenario

$$C = \frac{THQ \times BW_a \times AT_n}{EF_{CW} \times ED_{CW}\left[\left(\frac{1}{RfD_o} \times \frac{IRS_{CW}}{10^6\ mg/kg}\right) + \left(\frac{1}{RfD_o} \times \frac{SA_{CW} \times AF_{CW} \times ABS}{10^6\ mg/kg}\right) + \left(\frac{1}{RfD_i} \times \frac{IRA_{CW}}{VF\ or\ PEF_{CW}}\right)\right]}$$

Parameter	Definition (units)	Default
C	Contaminant concentration (mg/kg)	Chemical-specific
THQ	Target hazard quotient	1
AT_n	Averaging time, noncarcinogens (days)	ED x 365
EF_{CW}	Exposure frequency, construction (day/yr)	250
ED_{CW}	Exposure duration, construction (years)	1
IRS_{CW}	Soil ingestion rate, construction (mg/day)	330
RfD_o	Oral reference dose (mg/kg-day)	Chemical-specific
SA_{CW}	Dermal surface area, construction (cm^2/day)	3,300
AF_{CW}	Soil adherence factor, construction (mg/cm^2)	0.3
ABS	Skin absorption factor (unitless)	Chemical-specific
IRA_{CW}	Inhalation rate, construction (m^3/day)	20
RfD_i	Inhalation reference dose (mg/kg-day)	Chemical-specific
VF	Volatilization factor (m^3/kg)	See Equation 10
PEF	Particulate emission factor (m^3/kg)	See Equation 12

2.3.3 Alternative Evaluation for Lead

Exposure to lead can result in neurotoxic and developmental effects. The primary receptors of concern are children, whose nervous systems are still undergoing development and who also exhibit behavioral tendencies that increase their likelihood of exposure (e.g., pica). These effects may occur at exposures so low that they may be considered to have no threshold, and are evaluated based on a blood lead level (rather than the external dose as reflected the RfD/RfC methodology). Therefore, US EPA views it to be inappropriate to develop noncarcinogenic "safe" exposure levels (i.e., RfDs) for lead. Instead, US EPA's lead assessment workgroup has recommended the use of the Integrated Exposure Uptake Biokinetic (IEUBK) model that relates measured lead concentrations in environmental media with an estimated blood-lead level (US EPA 1994 and 1998b). The model is used to calculate a blood lead level in children when evaluating residential land use and in adults (based on a pregnant mother's capacity to contribute to fetal blood lead levels), or when evaluating occupational scenarios at sites where access by children is reliably restricted. The NMED SSLs presented in Appendix A include values for lead that were calculated by using the IEUBK to backcalculate a soil concentration for each receptor that would not result in an estimated blood-lead concentration of 10 μg/dL or greater (residential adult of 400 mg/kg and industrial and construction worker of 750 mg/kg)

2.4 SITE ASSESSMENT AND CHARACTERIZATION

The Site Assessment/Site Characterization phase is intended to provide additional spatial and contextual information about the site, which may be used to determine if there is any reason to believe that receptors and/or complete exposure pathways may exist at or in the locality of the site where a release of hazardous waste/constituents has occurred. In addition, the site assessment phase serves as the initial information gathering phase to determine whether potential exposures are sufficiently similar to those upon which the NMED SSLs are predicated to support comparison. Finally, this phase can help to identify for sites in need of a more detailed assessment of potential risk. The approach outlined herein is discussed in greater detail in the NMED Hazardous Waste Bureau (HWB) guidance document *Assessing Human Health Risks Posed by Chemicals: Screening-level Risk Assessment* (NMED 2000). A CSM providing a list of the potentially exposed receptors and potentially complete exposure pathways in the scoping report is used to determine whether further assessment (i.e., a screening level assessment) and/or interim measures are required or whether the site poses minimal threat to human and ecological receptors at or near the site.

The ultimate purpose of the site assessment phase is to address the question: Are exposure pathways complete with regard to contaminant contact by receptors? A complete site assessment will consists of several steps:

- Develop data quality objectives and conduct site sampling;
- Identify preliminary COPCs;
- Develop a preliminary site conceptual exposure model (SCEM); and
- Compare maximum (or, if deemed appropriate by NMED, the 95% upper confidence limit (UCL) value) for contaminant concentrations (or detection/quantitation limits for non-detect results) for consideration of complete exposure pathways with SSLs.

2.4.1 Development of Data Quality Objectives

Before any additional environmental samples are collected, data quality objectives (DQOs) should be developed. The DQOs should address the qualitative and quantitative nature of the sampling data, in terms of relative quality and intent for use, to ensure that any data collected will be appropriate for the intended objective. Development of the DQOs should consider not only precision, accuracy, representativeness, completeness, and comparability of the data, but also the sampling locations, types of laboratory analyses used, sensitivity of detection limits of the analytical techniques, the resulting data quality, and the employment of adequate quality assurance/quality control measures.

2.4.2 Identification of COPCs

COPCs are those substances (including transformation or breakdown compounds and companion products) likely to be present in environmental media affected by a release. Identification of COPCs should begin with existing knowledge of the process, product, or waste from which the release originated. For example, if facility operations deal primarily with pesticide manufacturing then pesticides should be considered COPCs. Contaminants identified during current or previous site investigation activities should also be evaluated as COPCs. A site-specific COPC list for soil may be generated based on maximum detected (or, if deemed appropriate by NMED, the 95% UCL value) concentrations (US EPA 2002b) and a comparison of detection/quantitation limits for non-detect results to the NMED SSLs. This list may be refined through a site-specific risk assessment.

2.4.3 Development of a Preliminary Conceptual Site Model

A CSM is a graphical representation of three-dimensional site conditions that conveys what is known or suspected, at a discrete point in time, about the site-specific sources, releases, release mechanisms, contaminant fate and transport, exposure routes, and potential receptors. The CSM is generally documented by written descriptions and supported by maps, geological cross-sections, tables, diagrams and other illustrations to communicate site conditions. When preparing a CSM, the facility should decide the scope, quantity, and relevance of information to be included, balancing the need to present as complete a picture as possible to document current site conditions and justify risk management actions, with the need to keep the information focused and exclude extraneous data.

As a final check, the CSM should answer the following questions:

- Are there potential land uses present (now or in the foreseeable future) other than those covered by the SSLs (refer to US EPA 1989).
- Are there other likely human exposure pathways that were not considered in development of the SSLs (e.g. direct exposure to groundwater, local fish consumption, raising beef, dairy, or other livestock)? (refer to US EPA 1989)
- Are there potential ecological concerns? (*Guidance for Assessing Ecological Risks Posed by Chemicals: Screening Level Ecological Risk Assessment*; NMED 2000)

If any conditions such as these exist, the SSLs may need to be adjusted to reflect this new information.

2.4.4 Compare COPC Maximum Concentrations With SSLs

The final step in the site assessment phase is to compare maximum detected COPC concentrations in soil (or, if deemed appropriate by NMED, the 95% UCL value on the mean of the dataset (US EPA 2002b)) with SSLs based on the complete exposure pathways identified by the preliminary CSM. These concentrations should also be compared against the SSL leaching values to determine which contaminants present in soil have the capacity to leach to underlying groundwater and impact these resources adversely. As stated earlier, those contaminants exhibiting concentrations in excess of the SSLs represent the initial soil COPC list for a given site. Refinement of this list may be necessary based on a host of factors, including elevated detection or quantitation limits.

3. Chemical-Specific and Physical-Chemical Parameters

Chemical-specific parameters required for calculating SSLs include the organic carbon normalized soil-water partition coefficient for organic compounds (K_{oc}), the soil-water partition coefficient (K_d), water solubility (S), octanol-water partition coefficient (K_{ow}), Henry's Law constant (H), diffusivity in air (D_a), and diffusivity in water (D_w). The following sections describe these values and present methodologies for calculating additional values necessary for calculating the NMED SSLs.

3.1 VOLATILIZATION FACTOR

Volatile chemicals, defined as those chemicals having a Henry's Law constant greater than 1 x 10^{-5} atm-m^3/mole-°K and a molecular weight less than 200 g/mole, were screened for inhalation exposures using a volatilization factor (VF) for soils. The soil-to-air VF is used to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to ambient air. The emission terms used in the VF are chemical-specific and were calculated from physical-chemical information obtained from several sources including: US EPA's *Soil Screening Guidance: Technical Background Document* (US EPA, 1996a and 2001a), USEPA Master Physical and Chemical Parameter table for development of PRGS (USEPA 2001b), the US EPA Region 9 *Preliminary Remediation Goals* (US EPA 2002a), EPA's *Basics of Pump and Treat Groundwater Remediation Technology* (US EPA 1990), US EPA's *Dermal Exposure Assessment* (US EPA 1992a*), Superfund Public Health Evaluation Manual* (US EPA 1986), EPA's *Additional Environmental Fate Constants* (US EPA 1995), Hazardous Substance Release/Health Effects Database (ATSDR 2003), and the CHEMFACTS Database (US EPA 2000c). The VF is calculated using Equation 10.

Equation 10
Derivation of the Volatilization Factor for Residential and Commercial/Industrial Scenarios

$$VF = \frac{Q/C_{vol} \times \left(3.14 \times D_A \times T\right)^{0.5} \times 10^{-4}}{\left(2 \times \rho_b \times D_A\right)}$$

Where:

$$D_A = \frac{\left[\frac{\left(\theta_a^{10/3} D_a H' + \theta_w^{10/3} D_w\right)}{n^2}\right]}{\rho_b K_d + \theta_w + \theta_a H'}$$

Parameter	Definition (units)	Default
VF	Volatilization factor (m^3/kg)	Chemical-specific
D_A	Apparent diffusivity (cm^2/s)	Chemical-specific
Q/C_{vol}	Inverse of the mean concentration at the center of a 0.5- acre-square source (g/m^2-s per kg/m^3)	68.18
T	Exposure interval (s)	9.5 x 10^8
ρ_b	Dry soil bulk density (g/cm^3)	1.5
n	Total soil porosity 1 - (ρ_b/ρ_s)	0.42
θ_a	Air-filled soil porosity (n - θ_w)	0.18
θ_w	Water-filled soil porosity	0.26
ρ_s	Soil particle density (g/cm^3)	2.65
D_a	Diffusivity in air (cm^2/s)	Chemical-specific

H'	Dimensionless Henry's Law constant	Chemical-specific
D_w	Diffusivity in water (cm^2/s)	Chemical-specific
K_d	Soil-water partition coefficient (cm^3/g) = K_{oc} x f_{oc} (organics)	Chemical-specific
K_{oc}	Soil organic carbon partition coefficient (cm^3/g)	Chemical-specific
f_{oc}	Fraction organic carbon in soil (g/g)	0.0015

While most of the parameters used to calculate apparent diffusivity (D_A) are either chemical-specific or default values, several state-specific values were used which are more representative of soil conditions found in New Mexico. The default values for θ_w, θ_a, and ρ_b in Equation 10 are 0.26, 0.18 and 1.5 g/cm^3, respectively. These values represent the mean value from a National Resources Conservation Service (NRCS) soil survey database for New Mexico that includes over 1200 sample points (U.S. Department of Agriculture 2000). USEPA guidance (2001a) provides additional methodologies for estimating site-specific air-filled soil porosities and water-filled soil porosities.

It should be noted that the basic principle of the VF model (Henry's Law) is applicable only if the soil contaminant concentration is at or below soil saturation, C_{sat}. Above the soil saturation limit, the model cannot predict an accurate VF-based SSL.

3.2 SOIL SATURATION LIMIT

C_{sat} describes a chemical-physical soil condition that integrates certain chemical-specific properties with physical attributes of the soil to estimate the contaminant concentration at which the soil pore water, pore air, and surface sorption sites are saturated with contaminants. Above this concentration, the contaminants may be present in free phase within the soil matrix – as non-aqueous phase liquids (NAPLs) for substances that are liquid at ambient soil temperatures, and pure solid phases for compounds that are solids at ambient soil temperatures (EPA 1996a). Generic C_{sat} concentrations should not be interpreted as confirmation of a saturated soil condition, but as estimates of when this condition may occur. It should be noted that C_{sat} concentrations are not risk-based values. Instead, they correspond to a theoretical threshold above which free phase contaminant may exist. C_{sat} concentrations, therefore, serve to identify an upper limit to the applicability of generic risk-based soil criteria, because certain default assumptions and models used in the generic algorithms are not applicable when free phase contaminant is present in soil. Equation 11, given below is used to calculate C_{sat} for each volatile contaminant considered within the SSLs.

Equation 11
Derivation of the Soil Saturation Limit

$$C_{sat} = \frac{S}{\rho_b}\left(K_d\rho_b + \theta_w + H'\theta_a\right)$$

Parameter	Definition (units)	Default
C_{sat}	Soil saturation concentration (mg/kg)	Chemical-specific
S	Solubility in water (mg/L-water)	Chemical-specific
ρ_b	Dry soil bulk density (kg/L)	1.5
K_d	Soil-water partition coefficient (L/kg; $K_{oc} \times f_{oc}$)	Chemical-specific
K_{oc}	Soil organic carbon/water partition coefficient (L/kg)	Chemical-specific
f_{oc}	Fraction organic carbon in soil (g/g)	0.0015
θ_w	Water-filled soil porosity	0.26
H´	Dimensionless Henry's Law constant	Chemical-specific
θ_a	Air-filled soil porosity (n- θ_{w})	0.18
n	Total soil porosity ($1 - (\rho_b/\rho_s)$)	0.42
ρ_s	Soil particle density (kg/L)	2.65

Chemical-specific parameters used in Equation 11 were obtained from physical-chemical information obtained from several sources including: US EPA's *Soil Screening Guidance: Technical Background Document* (US EPA 1996a), the US EPA Region 9 *Preliminary Remediation Goals* (US EPA 2002a), US EPA's *Basics of Pump and Treat Groundwater remediation Technology* (US EPA 1990), US EPA's *Dermal Exposure Assessment* (US EPA 1992a*), Superfund Public Health Evaluation Manual* (US EPA 1986), US EPA's *Additional Environmental Fate Constants* (US EPA 1995), Hazardous Substance Release/Health Effects Database (ATSDR 2003), and the CHEMFACTS Database.

3.3 PARTICULATE EMISSION FACTOR

Inhalation of chemicals adsorbed to suspended respirable particles is assessed using a chemical-specific PEF, which relates the contaminant concentration in soil to the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. This guidance addresses dust generated from open sources, which is termed "fugitive" because it is not discharged into the atmosphere in a confined flow stream. For further details on the methodology associated with the PEF model, the reader is referred to US EPA's *Soil Screening Guidance: Technical Background Document* (US EPA 1996a), *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (US EPA 2001a) and *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (US EPA 1998a).

It is important to note that the PEF for use in evaluating exposures of the residential and commercial/industrial receptors addresses only windborne dust emissions and does not consider emissions from traffic or other forms of mechanical disturbance, which could lead to a greater level of exposure. The PEF for use in evaluating the construction worker exposures considers windborne dust emissions and emissions from vehicle traffic associated with construction activities. Therefore, the fugitive dust pathway should be considered carefully when developing the CSM at sites where receptors may be exposed to fugitive dusts by other mechanisms. Equation 12 is used to calculate a New-Mexico region-specific PEF value, used for both the residential and commercial/industrial exposure scenarios. A scenario-specific PEF value was calculated for a construction worker receptor using Equation 13.

Equation 12
Derivation of the Particulate Emission Factor
Residential and Commercial/Industrial Scenarios

$$PEF = Q/C_{wind} \times \frac{3{,}600\ \text{sec/hr}}{0.036 \times (1 - V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x)}$$

Parameter	Definition (units)	Default
PEF	Particulate emission factor (m^3/kg)	1.61×10^9
Q/C_{wind}	Inverse of a mean concentration at center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	81.85
V	Fraction of vegetative cover (unitless)	0.5
U_m	Mean annual windspeed (m/s)	4.02
U_t	Equivalent threshold value of windspeed at 7 m (m/s)	11.32
F(x)	Function dependent on Um/Ut derived using Cowherd et al. (1985) (unitless)	0.0553

Equation 13
Derivation of the Particulate Emission Factor
Construction Worker Scenario

$$PEF_{CW} = Q/C_{CW} \times \frac{1}{F_D}\left[\frac{T \times A_R}{556 \times \left(\frac{W}{3}\right)^{0.4} \times \frac{(365\ days/yr\ -\ P)}{365\ days/yr} \times \sum VKT}\right]$$

Parameter	Definition (units)	Default
PEF_{CW}	Particulate emission factor (m^3/kg)	2.12E6
Q/C_{CW}	Inverse of a mean concentration at center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	23.02
F_D	Dispersion correction factor (unitless)	0.185
T	Total time over which construction occurs (s)	7.2E6
A_R	Surface area of road segment (m^2)	274.2
W	Mean vehicle weight (tons)	8
P	Number of days with at least 0.01 inches of precipitation (days/yr)	60
ΣVKT	sum of fleet vehicle kilometers traveled during the exposure duration (km)	168.75

3.4 PHYSICAL-CHEMICAL PARAMETERS

Several chemical-specific parameters are required for calculating SSLs including the organic carbon normalized soil-organic carbon/water partition coefficients for organic compounds (K_{oc}), the soil-water partition coefficient for organic and inorganic constituents (K_d), the solubility of a compound in water (S), Henry's Law constant (H), air diffusivity (D_a), water diffusivity (D_w), and the octanol-water partition coefficient (K_{ow}). Prior to calculating site-specific SSLs, each relevant chemical specific parameter value presented in Appendix B should be checked against the most recent version of its source to determine if updated data are available. Table B-1 in Appendix B provides the chemical-specific parameters used in calculating the NMED SSLs.

Chemical-specific values were obtained from EPA's *Soil Screening Guidance: Technical Background Document* (US EPA 1996a), the EPA Region 9 *Preliminary Remediation Goals* (US EPA 2002a), US EPA's *Basics of Pump and Treat Groundwater remediation Technology* (US EPA 1990), US EPA's *Dermal Exposure Assessment* (US EPA 1992a), *Superfund Public Health Evaluation Manual* (US EPA 1986), US EPA's *Additional Environmental Fate Constants* (US EPA 1995), Hazardous Substance Release/Health Effects Database (ATSDR 2003), and the CHEMFACTS Database.

3.4.1 Solubility, Henry's Law Constant, and K_{ow}

The solubility of a contaminant refers to the maximum amount that can be dissolved in a fixed volume of a solvent, usually pure water, at a specific temperature and pH. A chemical with a high solubility readily dissolves in water, while a low solubility indicates an inability to dissolve. Water solubility is generally predicted based on correlations with the octanol-water partition coefficient (K_{ow}). Solubility is used to calculate soil saturation limits for the NMED SSLs.

The octanol-water partition coefficient (K_{ow}) of a chemical is the ratio of a chemical's solubility in octanol versus its solubility in water at equilibrium. Essentially, this chemical-specific property is used as an indication of a contaminant's propensity to migrate from soil to water. It is an important parameter and is used in the assessment of environmental fate and transport for organic chemicals.

The Henry's Law constant (H) is used when evaluating air exposure pathways. For all chemicals that are capable of exchanging across the air-water interface, there is a point at which the rate of volatilization into the air and dissolution to the water or soil will be equal. The ratio of gas- and liquid-phase concentrations of the chemical at this equilibrium point is represented by H, which is used to determine the rate at which a contaminant will volatilize from soil to air. Values for H may be calculated using the following equation and the values for solubility (S), vapor pressure (VP), and molecular weight (MW).

$$H = \frac{VP \text{ x } MW}{S}$$

The dimensionless form of Henry's Law constant (H´) used in calculating soil saturation limits and volatilization factors for the NMED SSLs was calculated by multiplying H by a factor of 41 to convert the Henry's Law constant to a unitless value.

3.4.2 Soil Organic Carbon/Water Partition Coefficients (K_{oc})

The soil organic carbon-water partition coefficient (K_{oc}) is a measure of a chemical's tendency to adsorb to organic carbon present in soil. High K_{oc} values indicate a tendency for the chemical to adsorb to soil particles rather than remain dissolved in the soil solution. Strongly adsorbed molecules will not unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values of less than 500 indicate weak adsorption and a potential for leaching. K_{oc} is calculated using the following equation:

$$K_{oc} = \frac{\text{conc. adsorbed/conc. dissolved}}{\text{\% organic carbon in soil}}$$

K_{oc} can also be calculated by dividing the K_d value by the fraction of organic carbon (f_{oc}) present in the soil or sediment. It should be noted that a strong linear relationship exists between K_{oc} and K_{ow} and that this relationship can be used to predict K_{oc}.

3.4.3 Soil/Water Partition Coefficients (K_d)

Soil-water partition coefficient (K_d) for organic chemicals is the ratio of a contaminant's distribution between soil and water particles. The soil-water partitioning behavior of nonionizing and ionizing organic compounds differs because the partitioning of ionizing organics can be influenced by soil pH. K_d values were used in calculating soil saturation limits and volatilization factors used in developing the NMED SSLs.

For organic compounds, K_d represents the tendency of a chemical to adsorb to the organic carbon fraction in soils, and is represented by:

$$K_d = K_{oc} \text{ x } f_{oc}$$

where

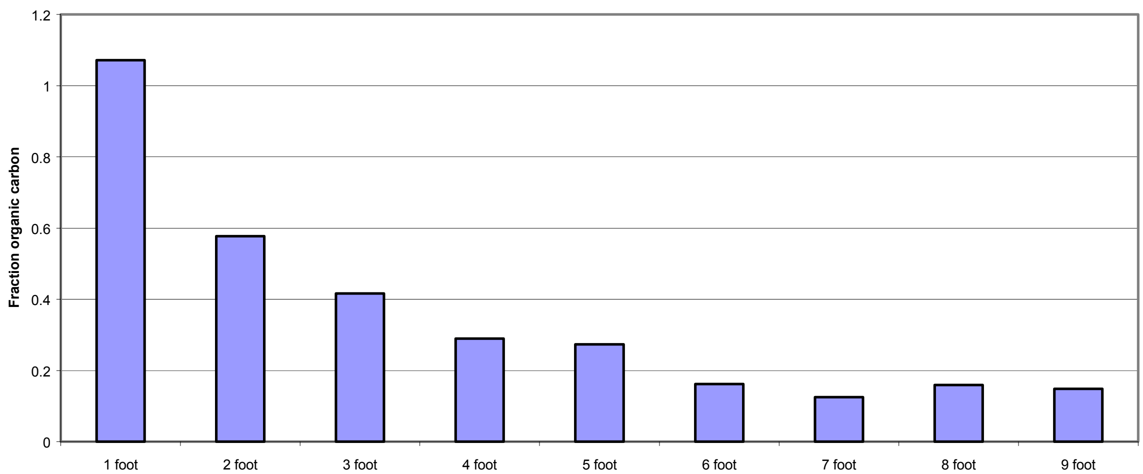
K_{oc} = organic carbon partition coefficient (L/kg); and
f_{oc} = fraction of organic carbon in soil (mg/mg).

This relationship is generally valid for volatile halogenated hydrocarbons as long as the fraction of organic carbon in soil is above approximately 0.001 (0.1 percent) (Piwoni and Banaerjee, 1989 Schwarzenbach and Westall 1981). For low organic carbon soils (f_{oc} < 0.001), Piwoni and Banerjee (1989) developed the following empirical correlation for organic chemicals:

$$\log K_d = 1.01 \log K_{ow} - 0.36$$

The use of a fixed K_{oc} value in the soil-water partition equation for the migration to groundwater pathway is only valid for hydrophobic non-ionizing organic chemicals. For organic chemicals that ionize in the soil environment, existing in both neutral and ionized forms within the normal soil pH range, K_{oc} values must consider the relative proportions and differences in sorptive properties of these forms. For the equations and applications of developing K_{oc} values for ionizing organic acids as a function of pH, the reader is referred to US EPA 1996. The default value used for f_{oc} in development of NMED SSLs is 0.0015 (0.15%). This value represents the median value of 212 data points included in the NRCS soil survey database for New Mexico (U.S. Department of Agriculture 2000). Only samples collected from a depth of greater than 5 feet were included in the calculation of the mean f_{oc} value. Shallow soil samples tend to have higher f_{oc} values as shown in Figure 2.1. There is a steady decline in f_{oc} value with depth until approximately 5 feet bgs. Below 5 feet, there is little variability in the f_{oc} value. Because a lower f_{oc} value provides a more conservative calculation of SSL, a value representative of deeper soil conditions is used as the default value.

Figure 2-1 Mean Value - Fraction Organic Carbon (f_{oc})-
All counties in New Mexico



As with organic chemicals, development of the NMED SSLs for inorganic constituents (i.e., metals) requires a soil-water partition coefficient (K_d) for each contaminant. K_d values for metals are affected by a variety of soil conditions, most notably pH, oxidation-reduction conditions, iron oxide content, soil organic matter content, cation exchange capacity and major ion chemistry. US EPA developed default K_d values for metals using either an equilibrium geochemical speciation model (MINTEQ2) or from empirical pH-dependent adsorption relationships developed by Environmental Protection Agency's Office of Research and Development (EPA/ORD) (US EPA 1996a).

4. Migration of Contaminants to Groundwater

Generic SSLs were developed which address the potential for migration of contaminants from soil to groundwater. The methodology used to calculate generic SSLs addresses the potential leaching of contaminants from the vadose zone to groundwater in excess of New Mexico WQCC standards. This method does not take into account any additional attenuation associated with contaminant transport in groundwater. The SSLs developed from this analysis are based on New Mexico specific values and are protective of groundwater under a wide range of site conditions. This methodology is modeled after US EPA's *Soil Screening Guidance: Technical Background Document* (US EPA 1996a).

4.1 Overview of the SSL Model Approach

Two approaches to developing soil leachate-based SSLs are presented, the generic model and the site-specific model. Both models use the same set of equations to calculate SSLs and are based on leaching to groundwater scenarios that NMED believes are protective of groundwater. The generic model calculates SSLs using default parameter values generally representative of conditions in New Mexico. These values are presented in Table B-1 of Appendix B. The site-specific model provides the flexibility of using site-specific meteorological, soil and hydrological data to calculate SSLs, while retaining the simplicity and ease of use associated with the generic model.

The development of soil leachate SSLs is based upon a two step process. The first step is the development of a Dilution Attenuation Factor (DAF). The DAF accounts for leachate mixing in the aquifer. A leachate concentration that is protective of ground water is back calculated by multiplying the ground water standard for a given constituent by the DAF. That leachate concentration is then used to back calculate an SSL that is protective of groundwater using a simple linear equilibrium soil/water partition equation. For the generic SSL approach, default parameter values are used for all non-chemical specific parameters. At sites that are not adequately represented by the default values and where more site-specific data are available, it may be more appropriate to use the site-specific SSL model. The site-specific model uses the same spreadsheet equations to calculate SSLs as those in the generic look-up table. However, site-specific data are used in the site-specific model.

The following sections of this document provide a general description of the leaching to groundwater pathway SSL model (generic and site-specific) including the assumptions, equations, and input parameters. Justification for the default parameters used in the generic model is also provided. Additionally, a sensitivity analysis was performed on each of the input parameters to provide guidance on when use of the site-specific model may be warranted. Applicability and limitations of the generic and site-specific models are also presented.

4.2 MODEL ASSUMPTIONS

Assumptions regarding the release and distribution of contaminants in the subsurface that are incorporated into the SSL methodology include the following.

- The source is infinite (a constant concentration is maintained for the duration of the exposure period).
- Contamination is uniformly distributed from the surface to the water table.
- Soil/water partitioning is instantaneous and follows a linear equilibrium isotherm.
- There is no attenuation of the contaminant in soil or the aquifer (i.e., irreversible adsorption, chemical transformation or biological degradation).
- The potentially impacted aquifer is unconfined and unconsolidated with homogenous and isotropic hydrologic properties.
- The receptor well (point of exposure) is at the downgradient edge of the source and is screened within the potentially impacted aquifer.
- Non-aqueous phase liquids (NAPLs) are not present.

4.3 SOIL WATER PARTITION EQUATION

US EPA's *Supplemental Soil Screening Guidance: Technical Background Document* (US EPA 2001) developed an equation to estimate contaminant release in soil leachate based on the Freundlich adsorption isotherm. The Freundlich equation was modified to relate the sorbed concentration to the total concentration measured in a soil sample (which includes contaminants associated with solid soil, soil-water and soil-air components) (Feenstra 1991). Equation 14, given below, is used to calculate SSLs corresponding to target soil leachate concentrations (C_w).

Equation 14
Soil Screening Level For Leaching To Groundwater Pathway

$$SSL = C_w \ x \left[K_d + \left(\frac{\theta_w + \theta_a H'}{\rho_b} \right) \right]$$

Parameter	Definition (units)	Default
SSL	Soil Screening Level for migration to groundwater pathway (mg/kg)	Chemical-Specific
C_w	Target soil leachate concentration (mg/L)	Chemical-Specific
K_d	Soil /water partition coefficient (L/kg)	Chemical-Specific
θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.26
θ_a	Air-filled soil porosity (L_{air}/L_{soil}), n - θ_w	0.18
n	Total soil porosity (L_{pore}/L_{soil}), 1 - (ρ_b/ρ_s)	0.42
ρ_s	Soil particle density (g/cm^3)	2.65
ρ_b	Dry soil bulk density (kg/L)	1.55
H´	Dimensionless Henry's Law constant	Chemical-Specific

Target soil leachate concentrations (C_w) are equivalent to the WQCC standards multiplied by a Dilution Attenuation Factor (DAF).

$$C_w = WQCC \ x \ DAF$$

The derivation of the DAF is discussed in subsequent sections of this document.

4.4 DILUTION ATTENUATION FACTOR

Contaminants transported as a leachate through soil to groundwater are affected by physical, chemical and biological processes that can significantly reduce their concentration. These processes include adsorption, biological degradation, chemical transformation and dilution from mixing of the leachate with groundwater. The total reduction in concentration between the source of the contaminant (vadose zone soil) and the point of ground water withdrawal is defined as the ratio of contaminant concentration in soil leachate to the concentration in groundwater at the point of withdrawal. This ratio is termed a dilution/attenuation factor (DAF; US EPA 1996a and 1996b). The higher the DAF value, the greater the degree of dilution and attenuation of contaminants along the migration flowpath. A DAF of 1 implies no reduction in contaminant concentration occurs.

Development of New Mexico SSLs considers only the dilution of contaminant concentration through mixing with groundwater in the aquifer directly beneath the source. This is consistent with the conservative assumptions used in the SSL methodology including an infinite source, soil contamination extending from surface to groundwater and the point of exposure occurring at the downgradient edge of the source. The ratio of contaminant concentration in soil leachate to the concentration in groundwater at the point of withdrawal that considers only dilution processes is calculated from a simple water balance equation (Equation 15), described below.

Equation 15
Dilution/Attenuation Factor (DAF)

$$DAF = 1 + \left(\frac{K \times i \times D}{I \times L} \right)$$

Where:

$$D = \left(0.0112 \times L^2\right)^{0.5} + D_a \left(1 - \exp\left[\frac{-L \times I}{K \times i \times D_a} \right] \right)$$

Parameter	Definition (units)	Default
DAF	Dilution/attenuation factor (unitless)	Site-Specific
K	Aquifer hydraulic conductivity (m/yr)	Site-Specific
i	Hydraulic gradient (m/m)	Site-Specific
D	Mixing zone depth (m)	Site-Specific
I	Infiltration rate (m/yr)	Site-Specific
L	Source length parallel to groundwater flow (m)	Site-Specific
D_a	Aquifer thickness (m)	Site-Specific

Most of these parameters are available from routine environmental site investigations. The mixing zone depth incorporates one additional parameter, the aquifer thickness (D_a).

For the calculation of SSLs, the DAF is used to back calculate the target soil leachate concentration from an appropriate groundwater concentration, such as the WQCC standard (C_w in Equation 14). For example, if the WQCC standard for a constituent is 0.1 mg/L and the DAF is 20, the target soil leachate concentration would be 2 mg/L.

The US EPA conducted an extensive evaluation of the range and distribution of DAFs to select a default value to be used for developing generic SSLs that would be reasonably protective of groundwater quality (US EPA 1996a, 1996b, and 2001). The evaluation included a probabilistic modeling exercise using US EPA's Composite Model for Leachate Migration with Transformation Products (CMTP). A cumulative frequency distribution of DAF values was developed from the model output. Results of the Monte Carlo modeling analysis indicate that for a 0.5 acre source area a DAF of approximately 170 is protective of groundwater at 90 percent of the sites. Groundwater is protected at 95 percent of the sites with a DAF of 7.

US EPA applied the simple SSL water balance dilution model (Equation 15) to 300 sites included in surveys of hydrogeologic investigations to further evaluate the range and distribution of DAF values. Results of this analysis indicated that a DAF of 10 was protective of groundwater for a 30-acre source and that a DAF of 20 was protective of groundwater for a 0.5 acre-source (US EPA 1996a, 1996b, and 2001).

An assessment was performed of US EPA's methodology to determine whether a default DAF value of 20 for a 0.5 acre source, and a DAF of 10 for a 30 acre source, would be appropriate for use as default values for sites in New Mexico. Typical New Mexico conditions may be notably different than conditions represented by areas included in the US EPA analysis of DAFs. For example, infiltration rates across much of New Mexico are substantially less than the average range of 0.15 to 0.24 m/yr reported for many of the hydrogeologic regions used in the US EPA analysis. In addition, effective porosity was assumed to be 0.35, presumably because this value is representative of the most prevalent aquifer type in the databases used (US EPA 1996a). However, the regions included in the EPA analysis also contain extensive glacial, regolith, lacustrine, swamp and marsh deposits which have high percentages of fine-grained sediments and thus are not representative of typical New Mexico sandy soils. Sandy soils typically have higher hydraulic conductivities than more fine-grained soils and subsequently higher Darcian velocities, under equal hydraulic gradient. According to the DAF equation (Equation 15), soils with relatively greater hydraulic conductivities will tend to result in a higher calculated DAF.

An assessment was made of input parameters to the DAF equation. In order to support a DAF that is protective of the most vulnerable groundwater environments in New Mexico (i.e. areas close to perennial streams or where ground water is very shallow), environmental parameters typical of those areas in New Mexico were used to assess the DAF. This assessment indicated that the DAF is most sensitive to variations in hydraulic conductivity. This is because this value shows such large variations in the natural environment. If a hydraulic conductivity value representative of a fine grained sand is used in the DAF equation, along with an infiltration rate representative of New Mexico's arid to semi-arid environments, then the result is a DAF of approximately 20. NMED believes that a DAF of 20 for a 0.5 acre source area is protective of groundwater in New Mexico. If the default DAF is not representative of conditions at a specific site, then it is appropriate to calculate a site-specific DAF based upon available site data.

4.5 LIMITATIONS ON THE USE OF THE DILUTION ATTENUATION FACTOR

Because of assumptions used in SSL model approach, use of the DAF model may be inappropriate for certain conditions, including sites where:

- adsorption or degradation processes are expected to significantly attenuate contaminant concentrations in the soil or aquifer media;
- Saturated thickness is significantly less than 12 meters thick;
- fractured rock or karst aquifer types exist (violates the unconfined, unconsolidated, homogeneous, isotropic assumptions);
- facilitated transport is significant (colloidal transport, transport via dissolved organic matter, or transport via solvents other than water; and/or
- NAPLs are present.

For sites that have these types of conditions, consideration should be given to application of a more detailed site-specific analysis than either the generic or site-specific models described herein. A discussion of these types of models is presented in Section 4.1.9.

4.6 Generic SSLs for Protection of Groundwater

The migration to groundwater pathway model, incorporating the assumptions, soil-water partition equation and the DAF, was used to develop NMED SSLs. Default values based on conditions predominant in New Mexico were used for the input parameters in the soil-water partition equation. The NMED SSLs were developed using default DAF values of 1 and 20.

Target soil leachate concentrations (C_w) are equivalent to the appropriate groundwater standards multiplied by a DAF. To maintain an approach that is protective of groundwater quality in the development of generic SSLs, a DAF of 20 is selected as reasonably protective. However SSLs are provided for two DAFs in Appendix A. The use of the SSL listed for a DAF of 20 is advised unless site-specific data on hydrologic conditions are available, and these indicate that the generic DAF is not representative of site conditions. As will be demonstrated in the sensitivity analysis section of this document, calculation of an SSL using the migration to groundwater pathway model is most sensitive to the DAF. The inclusion of the SSL for a DAF of 1 is provided for convenience to the user. If data on hydrologic conditions are readily available, a site specific DAF can be calculated and multiplied by the generic SSL for a DAF of 1 to provide a site-specific SSL.

The generic approach may be inappropriate for use at sites where conditions are substantially different from the default values used to develop the generic soil leachate SSLs.

4.7 Development of Site Specific SSLs for Protection of Groundwater

New Mexico, as with any other state, offers a variety of geologic and hydrologic conditions that may not be readily represented by a single default parameter value.

Site specific conditions may differ considerably from the typical or average conditions represented by the default values used to calculate generic SSLs. The site-specific model can be used to address the variability inherent in environmental conditions across and within the state.

Application of the site-specific model to develop soil leachate SSLs is the same as the generic approach except that site-specific values are used. Use of the site-specific model approach may incorporate replacement of all default values used for the generic SSLs with site-specific values, or may only include substitution of a single key parameter, such as hydraulic conductivity. The decision to use the site-specific model approach instead of the generic approach should be based on consideration of the sensitivity of the calculated SSL to specific parameters and the availability of those parameters as site-specific data. Sufficient site-specific data may be available such that each of the default values used for developing generic SSLs can be readily substituted with a more representative site-derived value. Conversely, limited site-specific data may restrict the number of default values to be replaced.

The NMED SSLs are generally more sensitive to the dilution factor than to other parameters in the soil-water partition equation. Fortunately, information needed to derive the DAF is usually available for sites that have undergone even the most basic levels of environmental investigation. Apart from the dilution factor, SSLs are most sensitive to the soil-water partition coefficient (K_d) as the values for this parameter can range over several orders of magnitude, particularly for metals. Although the K_d term may be critical in developing protective SSLs, information required to evaluate this parameter is more difficult to obtain and less likely to be available. Porosity and bulk density are not particularly sensitive because of the relatively small range of values encountered in subsurface conditions.

Using benzene as a representative contaminant, a sensitivity analysis was performed to compare a generic soil leachate SSL to site-specific model results simulating a range of model input parameters that might be representative of different conditions in New Mexico. The generic soil leachate SSL calculated using the New Mexico default values and a DAF of 1 is 2.8 μg/kg. These results are summarized in Table 4-1. As shown, the resulting SSLs for benzene range from 1.3 to 6.1 μg/kg for the various sensitivity simulations compared to the generic SSL of 2.8 μg/kg. These results indicate that the calculation of SSLs using the site-specific approach is not overly sensitive to the reasonable range of porosity (air and water filled), bulk density and fraction of organic carbon expected for New Mexico or even for a range of values for chemical-specific properties. The generic SSL for benzene of 2.8 μg/kg is representative of values that could be calculated using a spectrum of input parameters, exclusive of the DAF term. Unless there are sufficient data to calculate a site-specific DAF, there is little benefit derived from using the site-specific model approach instead of the generic SSL.

Table 4-1

Input Parameters and Resulting SSLs for the Sensitivity Analysis of the Soil-Water Partition Equation - Migration to Groundwater Pathway Model

Input parameter (NMED default value)	Sensitivity Analysis Values	Resulting SSLs
Bulk density	Lower Limit = 1.20	3.4
(default value = 1.55 gm/cm)	Upper Limit = 1.90	2.5
Air filled porosity	Lower Limit = 0.04[a]	1.3
(default value = 0.18)	Upper Limit = 0.25[b]	3.5
Fraction organic carbon	Lower Limit = 0.0005	2.2
(default value = 0.0015)	Upper Limit = 0.007	6.1
Volume water content	Lower Limit = 0.05[c]	1.8
(default value = 0.26)	Upper Limit = 0.40[c]	3.5
K_{oc}	Lower Limit = 30	2.4
(default value = 58.9 ml/g)	Upper Limit = 120	3.7
Dimensionless Henry's Law constant	Lower Limit = 0.1	2.7
(default value = 0.228)	Upper Limit = 0.4	3.0

[a] total porosity was reduced from 0.44 to 0.10 for this simulation
[b] total porosity was increased from 0.44 to 0.6 for this simulation
[c] total porosity remained at 0.44 for this simulation.

As previously stated, calculation of SSLs is most sensitive to the DAF term. The input parameter values and resulting DAFs for the sensitivity analysis are included in Table 4-2. Effects on the DAFs are, from greatest to least, the Darcian velocity (hydraulic conductivity multiplied by the hydraulic gradient), infiltration rates, size of the contaminated area, and the aquifer thickness. Corresponding effects on DAFs for each of these parameters and discussion of the relevance of the use of default values versus site-specific conditions are summarized below:

Table 4-2

Input Parameters and Resulting DAFs for the Sensitivity Analysis of the Dilution Attenuation Factor-Migration to Groundwater Pathway Model						
Parameter	**Groundwater Velocity (m/yr)**	**Infiltration Rate (m/yr)**	**Source Length (m)**	**Aquifer thickness (m)**	**Mixing Zone Depth (m)**	**Dilution Attenuation Factor (DAF)**
Groundwater velocity	2.2	0.13	45	12	7.15	3.7
Groundwater velocity	22	0.13	45	12	5.03	19.9
Groundwater velocity	220	0.13	45	12	4.79	181.1
Infiltration Rate	22	0.065	45	12	4.89	37.8
Infiltration Rate	22	0.13	45	12	5.03	19.9
Infiltration Rate	22	0.26	45	12	5.28	10.9
Source Length	22	0.13	22.5	12	2.51	19.9
Source Length	22	0.13	45	12	5.03	19.9
Source Length	22	0.13	348.4	12	38.76*	6.8
Aquifer Thickness	22	0.13	45	3	5.02*	12.3
Aquifer Thickness	22	0.13	45	12	5.03	19.9
Aquifer Thickness	22	0.13	45	48	5.03	19.9

Note: If mixing zone depth calculation is greater than aquifer thickness, then aquifer thickness is used to calculate the DAF.

Higher Darcian velocity results in higher DAFs. Slower mixing of groundwater with soil leachate occurs at lower groundwater velocity. Thus, using a lower velocity will be a more conservative approach. Sandy soils typically have higher hydraulic conductivities than more fine-grained soils and subsequently higher Darcian velocity (under equal hydraulic gradient). Use of a sandy soil type will generally be less conservative (result in higher DAFs) with respect to protection of groundwater quality.

Lower infiltration rates result in higher DAFs. Therefore, using a higher infiltration rate is a more conservative approach (results in a lower DAF).

Larger source sizes result in lower DAFs. The default DAF used to develop SSLs for a 0.5 acre source may not be protective of groundwater at sites larger than 0.5 acre. However, the selection of a second source size is arbitrary. If generic SSLs are developed for a 30 acre source, then those values are considered overly conservative for a 12 acre source. Conversely, SSLs developed for a 30 acre source will be less protective of a 40 acre source. Rather than develop a separate set of generic SSLs for a second (or third or fourth) source size, the following two approaches are proposed.

- As the size of the source area increases, the assumptions underlying the generic model are less applicable. One of the conservative assumptions in the generic SSL approach is the uniform distribution of contaminants throughout the vadose zone. There are few sites that have relatively uniform soil contamination (both laterally and vertically) of a single constituent in an area of greater than 0.5 acres (22,000 ft^2). Soil contamination at large facilities (such as federal facilities) are usually concentrated in discrete portions of the site. Contamination at large sites is commonly the result of multiple sources. It is advisable to attempt to subdivide the facility by source and contaminant type and then apply generic SSLs to those smaller source areas.

- If this approach is not practical, calculation of site specific DAFs is recommended.

> Most of the parameters required for these calculations are available from routine environmental site investigations or can be reasonably estimated from general geologic and hydrologic studies.

Thin aquifers will result in lower DAFs. The nominal aquifer thickness used in the sensitivity analysis was 12 m. Reducing the aquifer thickness to 3 m results in a 40 percent reduction in the DAF. Increasing the aquifer thickness beyond the nominal value has very little impact.

The significant effects of the DAF on the calculation of SSLs, coupled with the common availability of site-specific data used to calculate the DAF, suggest that use of the site specific modeling approach should at least incorporate recalculation of the DAF term. If data are available that indicate soil properties significantly different than the default values (such as high or low f_{oc} for organic contaminants, or highly acidic or basic conditions for metal contaminants) the K_d term should also be evaluated and recalculated.

4.8 Detailed Model Analysis for SSL Development

Sites that have complex or heterogeneous subsurface conditions may require more detailed evaluation for development of SSLs that are reasonably, but not overly, protective of groundwater and surface water resources. These types of sites may require more complex models that can address a wide range of variability in environmental site conditions including soil properties, contaminant mass concentration and distribution, contaminant degradation and transformation, recharge rates and recharge concentration, and depth to the water table. Model codes suitable for these types of more detailed analysis range from simple one-dimensional analytical models to complex three-dimensional numerical models. Resource requirements (data, time and cost) increase for the more complex codes. The selection of an appropriate code needs to balance the required accuracy of the output with the level of effort necessary to develop the model.

4.9 Summary of the Migration to Groundwater Pathway SSLs

SSLs for New Mexico have been developed for the migration to groundwater pathway, and are provided in Table A-1 of Appendix A. The NMED SSLs were developed using default parameter values representative of environmental conditions in New Mexico and utilize a DAF of 20. This approach maintains the conservative approach of the SSL methodology and is protective of groundwater quality under a wide range of site conditions. Soil contaminant concentrations can be compared directly to the generic SSLs to determine if additional investigation is necessary to evaluate potential leaching and migration of contaminants from the vadose zone to groundwater in excess of WQCC standards.

Site-specific SSLs can be developed by substituting site-related data for the default values in the leaching to groundwater pathway model. SSLs developed from this model are most sensitive to the DAF. SSLs are also provided in the lookup table for a DAF of 1. If data on hydrologic conditions are readily available, a site specific DAF can be calculated and multiplied by the generic SSL for a DAF of 1 to provide a site specific SSL.

5. Use of the SSLs

For screening sites with multiple contaminants, the following procedure should be followed: take the site-specific concentration (represented by the maximum reported concentration or, if deemed appropriate by NMED, the 95% UCL value for the concentration) and divide by the SSL concentration for each analyte. For multiple contaminants, simply add the ratio for each chemical.

$$\text{Site Risk} = \left(\frac{\text{conc}_x}{\text{SSL}_x} + \frac{\text{conc}_y}{\text{SSL}_y} + \frac{\text{conc}_z}{\text{SSL}_z} + \ldots + \frac{\text{conc}_i}{\text{SSL}_i} \right)$$

If the total ratio is greater than 1, then the concentrations at the site warrant further, site-specific evaluation. A ratio less than 1 indicates that the concentrations at the site are unlikely to result in adverse health impacts, or contaminate groundwater above State of New Mexico water quality standards.

As with any risk-based tool, the potential exists for misapplication. In most cases the root cause will be a lack of understanding of the intended use of NMED SSLs. In order to prevent misuse of SSLs, the following should be avoided:

- Applying SSLs to a site without adequately developing a conceptual site model that identifies relevant exposure pathways and exposure scenarios,
- Use of SSLs as cleanup levels without verifying numbers with a toxicologist or risk assessor, and
- Not considering the effects of additivity when screening multiple chemicals.

It is important to note that the generic NMED SSLs were developed assuming distinct soil horizons for each receptor. The soils of interest differ according to the exposure pathway being addressed. For direct ingestion, dermal, and fugitive dust pathways, the primary soil horizon of concern are surface soils. For inhalation of volatiles and migration to groundwater, subsurface soils are of primary concern. Both a residential receptor and a commercial/industrial worker are typically exposed only to surface soil, which may be defined as extending to a depth of approximately two feet below ground surface, depending on site-specific conditions and the amount of intrusive activity that may occur. Construction workers will typically have much greater exposures to subsurface soils. Therefore, when generic SSLs are used for screening level evaluations at a facility, site-specific conditions must be evaluated for each receptor to determine if the assumptions associated with the generic SSLs are appropriate for comparison with the available site data.

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APPENDIX A

Appendix A

State of New Mexico Soil Screening Levels

Table A-1 provides State of New Mexico Soil Screening Levels (SSLs), as developed by the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) and the Ground Water Quality Bureau Voluntary Remediation Program for 206 chemicals most commonly associated with environmental releases within the state. These NMED SSLs are derived using default exposure parameter values (as presented in Table A-2) and chemical- and State of New Mexico-specific physical parameters (as presented in Table B-1 of Appendix B). These default values are assumed to be appropriately conservative in the face of uncertainty and are likely to be protective for the majority of site conditions relevant to soil exposures within New Mexico.

However, the NMED SSLs are not necessarily protective of all known human exposure pathways, reasonable land uses or ecological threats. Thus, before applying NMED SSLs at a site, it is extremely important to compare the conceptual site model (CSM) with the assumptions upon which the NMED SSLs are predicated to ensure that the site conditions and exposure pathways match those used to develop the NMED SSLs. If this comparison indicates that the site at issue is more complex than the corresponding SSL scenarios, or that there are significant exposure pathways not accounted for by the NMED SSLs, then the NMED SSLs are insufficient for use in a defensible assessment of the site. A more detailed site-specific approach will be necessary to evaluate the additional pathways or site conditions.

<u>Table A-1</u>

Column 1: The first column in Table A-1 presents the names of the 206 chemicals for which NMED has developed SSLs.

Column 2: The second column presents NMED SSLs predicated on residential soil exposures.

Column 3: The third column presents indicator categories for the NMED SSL residential basis, whether predicated on carcinogenic effects (ca), noncarcinogenic effects (nc), soil saturation limits (sat) or a non-risk based "max" determination. NMED SSLs predicated on a carcinogenic endpoint reflect age-adjusted child-to-adult exposures. NMED SSLs predicated on a noncarcinogenic endpoint reflect child-only exposures. Detected concentrations above the "sat" value may indicate the presence of nonaqueous phase liquid (NAPL). For certain inorganic and semivolatile organic compounds (SVOCs) that exhibit relatively low toxicity, a non risk-based maximum concentration of 10^5 mg/kg is given when the risk-based SSL exceeds that level. These are noted as "max" in the tables.

Columns 4 and 6: The fourth and sixth columns present NMED SSLs analogous to Column 1, with the exception that these values correspond to Industrial/Occupational and Construction worker (adult-only) exposures, respectively.

Columns 5 and 7: The fifth and seventh columns present endpoint bases analogous to Column 3 for the Industrial/Occupational and Construction worker receptor populations, respectively. Unlike the Residential population, noncarcinogenic endpoint notes for these receptor populations are predicated on adult-only exposures.

Column 8: The eighth column notes which chemicals are considered VOCs (for inhalation considerations). Those chemicals not considered VOCs are evaluated within the SSLs relative to inhalation of particulate emissions.

Columns 9 and 10: The ninth column presents NMED SSLs for the migration to groundwater pathway developed using a default dilution attenuation factor (DAF) of 1, which assumes no effective dilution or attenuation. These values can be considered at sites where little or no dilution or attenuation of soil leachate concentrations is expected (e.g., shallow water tables, karst topography). Column 10 presents NMED SSLs for the migration to groundwater pathway developed using a DAF of 20 to account for natural processes that reduce contaminant concentrations in the subsurface.

As noted above, separate NMED SSLs are presented for use in evaluating three discrete potential receptor populations: Residential, Industrial/Occupational, and Construction. Each NMED SSL considers incidental ingestion of soil, inhalation of volatiles (limited to those chemicals noted as volatile organic compounds [VOCs] within Table A-1) or particulate emissions from impacted soil, and dermal contact with soil.

Generally, if a contaminant is detected at a level in soil exceeding the most relevant NMED SSL, and the site-specific CSM is in general agreement with the underlying assumptions upon which the NMED SSLs are predicated, this result indicates the potential for adverse human health effects to occur. Conversely, if no contaminants are detected above the most relevant NMED SSL, this tends to indicate to the user that environmental conditions may not necessitate remedial action of the surface soil or the vadose zone.

A detection above an NMED SSL does not indicate that unacceptable exposures are, in fact, occurring. The NMED SSLs are predicated on relatively conservative exposure assumptions and an exceedance only tends to indicate the potential for adverse effects. The NMED SSLs do not account for additive exposures, whether for carcinogenic or noncarcinogenic endpoints. Section 5 of Part A addresses a methodology by which an environmental manager may determine whether further site-evaluation is warranted, however, this methodology does not replace the need for defensible risk assessment where indicated.

The NMED SSLs address a basic subset of exposures fundamental to the widest array of environmentally-impacted sites within the State of New Mexico. The NMED SSLs cannot address all relevant exposure pathways associated with all sites. The utility of the NMED SSLs depends heavily upon the understanding of site conditions as accurately reflected in the CSM and nature and extent of contamination determinations. Consideration of the NMED SSLs does not preclude the need for site-specific risk assessment in all instances.

Table A-1
NMED Soil Screening Levels

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
Acenaphthene	4.69E+03	nc	3.48E+04	nc	1.44E+04	nc	X	3.99E+00	7.98E+01
Acetaldehyde	9.43E+01	nc	3.42E+02	nc	3.08E+02	nc	X	3.32E-04	6.63E-03
Acetone	7.04E+04	nc	1.00E+05	sat	1.00E+05	sat	X	1.03E-01	2.06E+00
Acrylonitrile	3.96E+00	ca	1.15E+01	ca	5.22E+01	nc	X	6.61E-06	1.32E-04
Acetophenone	1.31E+03	sat	1.31E+03	sat	1.31E+03	sat	X		
Acrolein	1.84E-01	nc	6.70E-01	nc	6.01E-01	nc	X	8.39E-06	1.68E-04
Aldrin	2.84E-01	ca	1.12E+00	ca	6.99E+00	nc		1.47E-02	2.94E-01
Aluminum	7.78E+04	nc	1.00E+05	max	1.44E+04	nc		7.50E+03	1.50E+05
Anthracene	2.35E+04	nc	2.64E+05	nc	8.53E+04	nc	X	8.00E+01	1.60E+03
Antimony	3.13E+01	nc	4.54E+02	nc	1.24E+02	nc		2.71E-01	5.42E+00
Arsenic	3.90E+00	ca	1.77E+01	ca	8.52E+01	nc		2.92E+00	5.83E+01
Barium	5.45E+03	nc	7.83E+04	nc	1.44E+03	nc		4.12E+01	8.23E+02
Benzene	2.70E+01	ca	7.36E+01	ca	1.57E+02	nc	X	1.41E-03	2.83E-02
Benzidine	2.11E-02	ca	8.33E-02	ca	7.09E-01	ca			
Benzo(a)anthracene	6.21E+00	ca	2.34E+01	ca	2.14E+02	ca		5.49E-02	1.10E+00
Benzo(a)pyrene	6.21E-01	ca	2.34E+00	ca	2.14E+01	ca		3.06E-01	6.12E+00
Benzo(b)fluoranthene	6.21E+00	ca	2.34E+01	ca	2.14E+02	ca		1.70E-01	3.40E+00
Benzo(k)fluoranthene	6.21E+01	ca	2.34E+02	ca	2.14E+03	ca		1.70E+00	3.40E+01
Beryllium	1.56E+02	nc	2.25E+03	nc	5.62E+01	nc		3.16E+00	6.32E+01
α-BHC	9.02E-01	ca	3.99E+00	ca	3.00E+01	ca		2.21E-05	4.43E-04
β-BHC	3.16E+00	ca	1.40E+01	ca	5.39E+01	nc		7.61E-05	1.52E-03
γ-BHC	4.37E+00	ca	1.93E+01	ca	8.09E+01	nc		3.55E-04	7.09E-03
1,1-Biphenyl	8.90E+01	sat	8.90E+01	sat	8.90E+01	sat	X	3.56E+00	7.12E+01
Bis(2-chloroethyl) ether	2.04E+00	ca	5.95E+00	ca	9.09E+01	ca	X	1.87E-06	3.75E-05
Bis(2-chloroisopropyl) ether	3.13E+03	nc	6.19E+03	nc	4.24E+03	nc	X	7.04E-05	1.41E-03
Bis(2-ethylhexyl) phthalate	3.47E+02	ca	1.37E+03	ca	4.66E+03	nc		1.09E+02	2.17E+03
Bis(chloromethyl) ether	4.26E-03	ca	1.10E-02	ca	2.11E-01	ca	X	8.87E-09	1.77E-07
Boron	5.50E+03	nc	6.16E+04	nc	2.14E+04	nc			

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
Bromobenzene	3.32E+01	nc	1.22E+02	nc	1.09E+02	nc	X	1.03E-02	2.06E-01
Bromodichloromethane	1.03E+02	ca	5.13E+02	ca	1.05E+03	nc	X	4.64E-05	9.28E-04
Bromomethane	7.62E+00	nc	2.92E+01	nc	2.52E+01	nc	X	1.84E-03	3.67E-02
1,3-Butadiene	8.91E-01	ca	2.13E+00	ca	4.11E+00	nc	X	1.32E-05	2.63E-04
2-Butanone (MEK)	5.73E+02	nc	2.10E+03	nc	1.88E+03	nc	X	3.32E-01	6.63E+00
tert-Butyl methyl ether (MTBE)	9.80E+02	ca	3.18E+03	ca	4.07E+04	ca	X	2.33E-03	4.67E-02
n-Butylbenzene	6.20E+01	sat	6.20E+01	sat	6.20E+01	sat	X	1.06E+00	2.13E+01
sec-Butylbenzene	6.05E+01	sat	6.05E+01	sat	6.05E+01	sat	X	8.54E-01	1.71E+01
tert-Butylbenzene	1.06E+02	sat	1.06E+02	sat	1.06E+02	sat	X	8.47E-01	1.69E+01
Cadmium[a]	7.41E+01	nc	8.60E+03	nc	4.74E-03	nc		3.76E-01	7.52E+00
Carbon disulfide	3.76E+03	nc	2.14E+04	nc	1.34E+04	nc	X	3.76E-01	7.52E+00
Carbon tetrachloride	3.13E+00	ca	7.75E+00	ca	9.06E+00	nc	X	2.87E-03	5.74E-02
Chlordane	1.62E+01	ca	7.19E+01	ca	1.30E+02	nc		3.61E-01	7.21E+00
2-Chloroacetophenone	4.07E-02	nc	1.48E-01	nc	1.33E-01	nc	X	4.35E-05	8.70E-04
2-Chloro-1,3-butadiene	5.64E+00	nc	2.05E+01	nc	1.84E+01	nc	X	5.51E-03	1.10E-01
1-Chloro-1,1-difluoroethane	2.05E+02	sat	1.00E+05	sat	1.00E+05	sat	X	6.36E+01	1.27E+03
Chlorobenzene	1.76E+02	nc	2.42E+02	sat	2.42E+02	sat	X	5.14E-02	1.03E+00
1-Chlorobutane	2.91E+02	sat	2.91E+02	sat	2.91E+02	sat	X	9.45E-01	1.89E+01
Chlorodifluoromethane	2.05E+02	sat	1.00E+05	sat	1.00E+05	sat	X	6.21E+01	1.24E+03
Chloroethane	1.38E+03	sat	1.38E+03	sat	1.38E+03	sat	X	1.12E-03	2.23E-02
Chloroform	3.56E+00	ca	8.52E+00	ca	1.88E+01	nc	X	2.45E-02	4.90E-01
Chloromethane	1.95E+01	ca	4.77E+01	ca	2.53E+02	nc	X	5.01E-04	1.00E-02
β-Chloronaphthalene	6.26E+03	nc	2.58E+04	nc	1.40E+04	nc	X	1.26E+00	2.52E+01
o-Chloronitrobenzene	1.69E+00	nc	6.23E+00	nc	5.54E+00	nc	X	3.98E-05	7.96E-04
p-Chloronitrobenzene	1.24E+01	nc	5.09E+01	nc	4.15E+01	nc	X	3.18E-04	6.37E-03
2-Chlorophenol	3.91E+02	nc	8.07E+02	nc	5.47E+02	nc	X	2.31E-02	4.62E-01
2-Chloropropane	2.87E+02	nc	6.89E+02	sat	6.89E+02	sat	X	4.34E-02	8.68E-01
o-Chlorotoluene	1.56E+03	nc	7.74E+02	nc	6.46E+02	nc	X	5.09E-02	1.02E+00
Chromium III	1.00E+05	max	1.00E+05	max	1.00E+05	max		9.90E+06	1.98E+08
Chromium VI	2.34E+02	nc	3.40E+03	nc	1.80E+02	ca		9.58E-01	1.92E+01
Chrysene	6.21E+02	ca	2.34E+03	ca	2.14E+04	ca	X	5.49E+00	1.10E+02

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
Cobalt	1.52E+03	nc	2.05E+04	nc	6.10E+01	nc		2.26E+00	4.52E+01
Copper	3.13E+03	nc	4.54E+04	nc	1.24E+04	nc		3.52E+01	7.03E+02
Crotonaldehyde	3.37E+00	ca	1.67E+01	ca	5.18E+01	sat	X	1.53E-05	3.06E-04
Cumene (isopropylbenzene)	7.00E+02	nc	2.73E+03	nc	2.32E+03	nc	X	3.65E-01	7.29E+00
Cyanide	1.56E+03	nc	2.27E+04	nc	6.19E+03	nc		3.88E-02	7.75E-01
Cyanogen	3.13E+03	nc	8.22E+02	nc	7.11E+02	nc	X	5.55E-02	1.11E+00
Cyanogen bromide	7.04E+03	nc	1.85E+03	nc	1.60E+03	nc	X	1.27E-01	2.54E+00
Cyanogen chloride	3.91E+03	nc	1.03E+03	nc	8.88E+02	nc	X	6.93E-02	1.39E+00
DDD	2.44E+01	ca	1.11E+02	ca	8.29E+02	ca		4.20E-01	8.40E+00
DDE	1.72E+01	ca	7.81E+01	ca	5.85E+02	ca		1.34E+00	2.68E+01
DDT	1.72E+01	ca	7.81E+01	ca	1.38E+02	nc		7.89E-01	1.58E+01
Dibenz(a,h)anthracene	6.21E-01	ca	2.34E+00	ca	2.14E+01	ca		5.24E-02	1.05E+00
Dibenzofuran	3.13E+02	nc	3.17E+03	nc	1.09E+03	nc	X	2.85E-01	5.70E+00
1,2-Dibromo-3-chloropropane	3.64E+00	nc	1.32E+01	nc	1.19E+01	nc	X	1.01E-05	2.02E-04
Dibromochloromethane	7.62E+01	ca	3.79E+02	ca	1.39E+03	nc	X	1.14E-04	2.28E-03
1,2-Dibromoethane	7.14E-02	ca	3.36E-01	ca	2.47E+00	ca	X	2.11E-05	4.23E-04
1,4-Dichloro-2-butene	1.33E-01	ca	3.17E-01	ca	7.14E+00	ca	X	2.89E-07	5.78E-06
1,2-Dichlorobenzene	1.16E+02	sat	1.16E+02	sat	1.16E+02	sat	X	4.46E-01	8.93E+00
1,3-Dichlorobenzene	7.04E+01	nc	7.39E+01	nc	5.70E+01	nc	X	6.09E-03	1.22E-01
1,4-Dichlorobenzene	3.60E+01	ca	8.14E+01	sat	8.14E+01	sat	X	8.27E-02	1.65E+00
3,3-Dichlorobenzidine	1.08E+01	ca	4.26E+01	ca	3.71E+02	ca		1.88E-04	3.76E-03
Dichlorodifluoromethane	1.44E+02	nc	2.05E+02	sat	2.05E+02	sat	X	2.85E-01	5.70E+00
1,1-Dichloroethane	8.20E+02	nc	1.22E+03	sat	1.22E+03	sat	X	6.05E-03	1.21E-01
1,2-Dichloroethane	5.07E+00	ca	1.26E+01	ca	5.33E+01	nc	X	9.92E-04	1.98E-02
cis-1,2-Dichloroethene	7.82E+02	nc	2.67E+02	nc	2.28E+02	nc	X	1.68E-02	3.37E-01
trans-1,2-Dichloroethene	1.56E+03	nc	3.98E+02	nc	3.44E+02	nc	X	2.91E-02	5.82E-01
1,1-Dichloroethene	1.82E+02	nc	6.86E+02	nc	6.01E+02	nc	X	1.92E-03	3.84E-02
2,4-Dichlorophenol	1.80E+02	nc	2.05E+03	nc	6.99E+02	nc		1.22E-02	2.45E-01
1,2-Dichloropropane	1.00E+01	nc	3.64E+01	nc	3.28E+01	nc	X	3.94E-05	7.89E-04
1,3-Dichloropropene	1.13E+01	ca	2.98E+01	ca	8.38E+01	nc	X	1.28E-04	2.56E-03
Dicyclopentadiene	2.35E+03	nc	2.13E+00	nc	1.92E+00	nc	X	4.51E-04	9.02E-03

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
Dieldrin	3.04E-01	ca	1.20E+00	ca	1.02E+01	ca		1.36E-04	2.71E-03
Diethyl phthalate	4.80E+04	nc	1.00E+05	max	1.00E+05	max		1.74E+01	3.48E+02
Dimethyl phthalate	1.00E+05	max	1.00E+05	max	1.00E+05	max		1.66E+02	3.31E+03
Di-n-butyl phthalate	6.00E+03	nc	6.84E+04	nc	2.33E+04	nc		1.84E+02	3.67E+03
2,4-Dimethylphenol	1.20E+03	nc	1.37E+04	nc	4.66E+03	nc		4.27E-02	8.54E-01
2,4-Dinitrotoluene	1.20E+02	nc	1.37E+03	nc	4.66E+02	nc		2.27E-02	4.54E-01
1,2-Diphenylhydrazine	6.08E+00	ca	2.39E+01	ca	2.04E+02	ca		9.73E-05	1.95E-03
Endosulfan	3.60E+02	nc	4.10E+03	nc	1.40E+03	nc		7.43E-01	1.49E+01
Endrin	1.80E+01	nc	2.05E+02	nc	6.99E+01	nc		3.72E-02	7.45E-01
Epichlorohydrin	1.51E+01	nc	5.90E+01	nc	5.01E+01	nc	X	3.46E-04	6.93E-03
Ethyl acetate	7.04E+04	nc	1.00E+05	sat	2.06E+04	sat	X	1.41E+00	2.83E+01
Ethyl acrylate	5.13E+01	sat	6.62E+02	ca	4.52E+03	ca	X	5.90E-04	1.18E-02
Ethyl chloride	1.38E+03	sat	1.38E+03	sat	7.48E+04	ca	X	1.12E-03	2.23E-02
Ethyl ether	1.89E+03	sat	1.89E+03	sat	1.89E+03	sat	X	2.27E-01	4.53E+00
Ethyl methacrylate	5.18E+01	sat	5.18E+01	sat	5.18E+01	sat	X	1.42E+00	2.85E+01
Ethylbenzene	1.06E+04	ca	2.54E+04	ca	5.71E+05	ca	X	5.25E-01	1.05E+01
Ethylene oxide	2.47E+00	ca	7.39E+00	ca	1.08E+02	ca	X	4.11E-06	8.23E-05
Fluoranthene	2.25E+03	nc	2.44E+04	nc	8.73E+03	nc		2.41E+02	4.82E+03
Fluorene	3.13E+03	nc	2.94E+04	nc	1.06E+04	nc	X	5.01E+00	1.00E+02
Furan	7.82E+01	nc	1.88E+01	nc	1.63E+01	nc	X	1.29E-03	2.58E-02
Heptachlor	1.08E+00	ca	4.26E+00	ca	3.63E+01	ca			
Hexachlorobenzene	3.04E+00	ca	1.20E+01	ca	1.02E+02	ca		8.27E-02	1.65E+00
Hexachloro-1,3-butadiene	1.20E+01	nc	1.37E+02	nc	4.66E+01	nc		8.08E-02	1.62E+00
Hexachlorocyclopentadiene	1.25E+02	nc	4.10E+03	nc	4.31E+02	nc		1.50E+01	3.00E+02
Hexachloroethane	6.00E+01	nc	6.84E+02	nc	2.33E+02	nc		1.37E-02	2.74E-01
n-Hexane	3.80E+01	sat	3.80E+01	sat	3.80E+01	sat	X	7.29E-01	1.46E+01
HMX	3.00E+03	nc	3.42E+04	nc	1.17E+04	nc			
Hydrogen cyanide	1.99E+01	nc	7.31E+01	nc	6.53E+01	nc	X	1.20E-03	2.40E-02
Indeno(1,2,3-c,d)pyrene	6.21E+00	ca	2.34E+01	ca	2.14E+02	ca		4.79E-01	9.58E+00
Iron	2.35E+04	nc	1.00E+05	max	9.29E+04	nc		3.27E+00	6.54E+01
Isobutanol	2.22E+04	sat	2.22E+04	sat	2.22E+04	sat	X	4.69E-01	9.39E+00

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
Isophorone	5.12E+03	ca	2.02E+04	ca	4.66E+04	nc		1.69E-02	3.38E-01
Lead	4.00E+02		7.50E+02	nc	7.50E+02	nc		4.58E-01	9.17E+00
Lead (tetraethyl-)	6.11E-03	nc	6.84E-02	nc	2.38E-02	nc			
Maleic hydrazide	1.57E+03	sat	1.57E+03	sat	1.57E+03	sat	X	7.86E-01	1.57E+01
Manganese	1.55E+03	nc	2.18E+04	nc	1.48E+02	nc		5.24E-02	1.05E+00
Mercury (elemental)	2.35E+01	nc	3.41E+02	nc	8.44E+01	nc			
Mercury (methyl)	6.11E+00	nc	6.84E+01	nc	2.38E+01	nc			
Methacrylonitrile	3.61E+00	nc	2.00E+01	nc	1.28E+01	nc	X	1.69E-04	3.39E-03
Methomyl	1.96E+03	nc	2.83E+02	nc	2.49E+02	nc	X	5.64E-02	1.13E+00
Methyl acetate	7.82E+04	nc	1.00E+05	sat	1.00E+05	nc	X	1.03E+02	2.06E+03
Methyl acrylate	2.35E+03	nc	3.12E+02	nc	2.75E+02	nc	X	4.62E-01	9.24E+00
Methyl isobutyl ketone	5.43E+03	nc	6.90E+03	sat	6.90E+03	sat	X	5.81E-02	1.16E+00
Methyl methacrylate	2.83E+03	sat	2.83E+03	sat	2.83E+03	sat	X	2.64E-01	5.29E+00
Methyl styrene (alpha)	2.16E+02	sat	2.16E+02	sat	2.16E+02	sat	X	3.09E-01	6.18E+00
Methyl styrene (mixture)	1.28E+02	nc	2.16E+02	sat	2.16E+02	sat	X	4.31E-02	8.62E-01
Methylcyclohexane	2.10E+03	nc	7.63E+03	nc	6.87E+03	nc	X	1.35E+01	2.69E+02
Methylene bromide	1.12E+02	nc	4.54E+02	nc	3.74E+02	nc	X	1.28E-02	2.56E-01
Methylene chloride	1.65E+02	ca	4.40E+02	ca	2.55E+03	sat	X	8.44E-04	1.69E-02
Molybdenum	3.91E+02	nc	5.68E+03	nc	1.55E+03	nc		2.02E+01	4.03E+02
Naphthalene	7.19E+01	nc	9.83E+01	sat	9.83E+01	sat	X	1.97E-02	3.93E-01
Nickel	1.56E+03	nc	2.25E+04	nc	5.61E+02	nc		1.30E+01	2.61E+02
Nitrate	1.00E+05	max	1.00E+05	max	1.00E+05	max			
Nitrite	7.82E+03	nc	1.00E+05	max	3.10E+04	nc			
Nitrobenzene	2.18E+01	nc	1.36E+02	nc	7.89E+01	nc	X	9.00E-04	1.80E-02
Nitroglycerin	3.47E+02	ca	1.37E+03	ca	1.19E+04	ca			
N-Nitrosodiethylamine	3.24E-02	ca	1.28E-01	ca	1.09E+00	ca			
N-Nitrosodimethylamine	9.54E-02	ca	3.76E-01	ca	3.20E+00	ca		1.15E-06	2.31E-05
N-Nitrosodi-*n*-butylamine	2.48E-01	ca	6.67E-01	ca	1.16E+01	ca	X	1.12E-06	2.24E-05
N-Nitrosodiphenylamine	9.93E+02	ca	3.91E+03	ca	3.40E+04	ca		2.94E-02	5.89E-01
N-Nitrosopyrrolidine	2.32E+00	ca	9.12E+00	ca	7.77E+01	ca			
m-Nitrotoluene	4.10E+02	nc	5.57E+02	sat	5.57E+02	sat	X	1.62E-02	3.24E-01

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
o-Nitrotoluene	4.10E+02	nc	5.57E+02	sat	5.57E+02	sat	X	1.62E-02	3.24E-01
p-Nitrotoluene	4.10E+02	nc	5.57E+02	sat	5.57E+02	sat	X	1.62E-02	3.24E-01
Pentachlorobenzene	4.80E+01	nc	5.47E+02	nc	1.86E+02	nc		1.00E+00	2.00E+01
Pentachlorophenol	2.98E+01	ca	1.00E+02	ca	1.03E+03	ca		1.06E-03	2.11E-02
Phenanthrene	1.80E+03	nc	2.05E+04	nc	6.99E+03	nc		3.81E+00	7.62E+01
Phenol	1.80E+04	nc	1.00E+05	max	6.99E+04	nc		1.05E-03	2.11E-02
Polychlorinatedbiphenyls		ca		ca		ca			
Aroclor 1016	2.22E+00	ca	8.26E+00	ca	1.50E+01	nc			
Aroclor 1221	2.22E+00	ca	8.26E+00	ca	7.61E+01	ca			
Aroclor 1232	2.22E+00	ca	8.26E+00	ca	7.61E+01	ca			
Aroclor 1242	2.22E+00	ca	8.26E+00	ca	7.61E+01	ca			
Aroclor 1248	2.22E+00	ca	8.26E+00	ca	7.61E+01	ca			
Aroclor 1254	1.11E+00	nc	8.26E+00	ca	4.28E+00	nc			
Aroclor 1260	2.22E+00	ca	8.26E+00	ca	7.61E+01	ca			
n-Propylbenzene	5.32E+01	sat	5.32E+01	sat	5.32E+01	sat	X	1.06E+00	2.13E+01
Propylene oxide	2.17E+01	ca	9.01E+01	ca	7.91E+02	ca	X	4.52E-05	9.05E-04
Pyrene	2.30E+03	nc	3.13E+04	nc	9.05E+03	nc	X	2.84E+01	5.68E+02
RDX	4.42E+01	ca	1.74E+02	ca	6.99E+02	nc			
Selenium	3.91E+02	nc	5.68E+03	nc	1.55E+03	nc		2.58E-01	5.17E+00
Silver	3.91E+02	nc	5.68E+03	nc	1.55E+03	nc		4.23E-01	8.47E+00
Strontium	4.69E+04	nc	1.00E+05	max	1.00E+05	max		2.03E+02	4.06E+03
Styrene	4.19E+02	sat	4.19E+02	sat	4.19E+02	sat	X	1.35E-01	2.70E+00
1,2,4,5-Tetrachlorobenzene	1.80E+01	nc	2.05E+02	nc	6.99E+01	nc			
1,1,1,2-Tetrachloroethane	3.93E+01	ca	1.03E+02	ca	8.55E+02	sat	X	1.33E-04	2.66E-03
1,1,2,2-Tetrachloroethane	5.20E+00	ca	1.36E+01	ca	2.56E+02	ca	X	1.70E-05	3.40E-04
Tetrachloroethene	9.83E+00	ca	2.46E+01	ca	9.76E+01	sat	X	3.22E-04	6.44E-03
Thallium	5.16E+00	nc	7.49E+01	nc	2.04E+01	nc		1.42E-01	2.85E+00
Toluene	2.48E+02	sat	2.48E+02	sat	2.48E+02	sat	X	3.40E-01	6.80E+00
Toxaphene	4.42E+00	ca	1.74E+01	ca	1.48E+02	ca		2.35E-02	4.71E-01
Tribromomethane	8.11E+02	ca	4.02E+03	ca	6.02E+03	nc		3.01E-02	6.02E-01
1,1,2-Trichloro-1,2,2-trifluoroethane	3.18E+03	max	1.00E+05	max	1.00E+05	max	X		

Chemical	Residential Soil (mg/kg)	Endpoint	Industrial/ Occupational Soil (mg/kg)	Endpoint	Construction Worker Soil (mg/kg)	Endpoint	VOC	DAF 1 (mg/kg)	DAF 20 (mg/kg)
1,2,4-Trichlorobenzene	6.51E+02	nc	8.53E+02	sat	8.53E+02	sat	X	1.99E-01	3.98E+00
1,1,1-Trichloroethane	5.51E+02	sat	5.51E+02	sat	5.51E+02	sat	X	2.49E-02	4.98E-01
1,1,2-Trichloroethane	1.07E+01	ca	2.70E+01	ca	1.75E+02	nc	X	1.24E-03	2.47E-02
Trichloroethene	6.48E-01	ca	1.59E+00	ca	3.41E+01	ca	X	2.33E-03	4.66E-02
Trichlorofluoromethane	5.28E+02	nc	9.59E+02	sat	9.59E+02	sat	X	1.13E+00	2.27E+01
2,4,5-Trichlorophenol	6.00E+03	nc	6.84E+04	nc	2.33E+04	nc		9.24E+00	1.85E+02
2,4,6-Trichlorophenol	6.00E+00	nc	6.84E+01	nc	2.33E+01	nc		2.66E-03	5.32E-02
1,1,2-Trichloropropane	2.27E+01	nc	8.61E+01	nc	7.49E+01	nc	X	1.15E-02	2.30E-01
1,2,3-Trichloropropane	3.20E+00	ca	1.59E+01	ca	1.69E+01	nc	X	2.08E-06	4.17E-05
1,2,3-Trichloropropene	1.78E+01	nc	6.67E+01	nc	5.85E+01	nc	X	1.12E-02	2.23E-01
Triethylamine	6.36E+01	nc	2.31E+02	nc	2.08E+02	nc	X	2.06E-03	4.12E-02
1,2,4-Trimethylbenzene	5.22E+01	nc	1.91E+02	nc	1.71E+02	nc	X	6.89E-02	1.38E+00
1,3,5-Trimethylbenzene	2.23E+01	nc	6.89E+01	sat	6.89E+01	sat	X	1.72E-02	3.44E-01
2,4,6-Trinitrotoluene	3.00E+01	nc	3.42E+02	nc	1.17E+02	nc			
Vanadium	5.48E+02	nc	7.95E+03	nc	2.17E+03	nc		4.03E+01	8.07E+02
Vinyl acetate	9.53E+02	nc	3.49E+03	nc	3.12E+03	nc	X	7.30E-02	1.46E+00
Vinyl bromide	5.67E+00	nc	2.06E+01	nc	1.85E+01	nc	X	3.93E-05	7.86E-04
Vinyl chloride (Child)	3.49E-01	ca							
Vinyl chloride (adult)			1.30E+01	ca	1.74E+02	ca	X	3.25E-04	6.49E-03
m-Xylene	8.00E+01	sat	8.00E+01	sat	8.00E+01	sat	X	8.13E+00	1.63E+02
o-Xylene	9.86E+01	sat	9.86E+01	sat	9.86E+01	sat	X	7.37E+00	1.47E+02
p-Xylene	1.24E+02	sat	1.24E+02	sat	1.24E+02	sat	X	7.88E+00	1.58E+02
Xylenes	1.32E+02	sat	1.32E+02	sat	1.32E+02	sat	X	5.07E-01	1.01E+01
Zinc	2.35E+04	nc	1.00E+05	max	9.29E+04	nc		6.22E+02	1.24E+04

Notes: [a] - An oral absorption efficiency of 5% was assumed for the dermal route.
ca – carcinogenic effect basis
nc – noncarcinogenic effect basis
sat – soil saturation limit basis
max – low toxicity maximum, health based SSL exceeds 10^5 mg/kg
Compounds solid at ambient temperature will present a risk-based level over the soil saturation level (USEPA 2001a)

Table A-2

Default Exposure Factors			
Symbol	**Definition (units)**	**Default**	**Reference**
CSF_o	Cancer slope factor oral $(mg/kg\text{-}day)^{-1}$	Chem.-spec.	IRIS, HEAST, or NCEA
CSF_i	Cancer slope factor inhaled $(mg/kg\text{-}day)^{-1}$	Chem.-spec.	IRIS, HEAST, or NCEA
RfD_o	Reference dose oral (mg/kg-day)	Chem.-spec.	IRIS, HEAST, or NCEA
RfD_i	Reference dose inhaled (mg/kg-day)	Chem.-spec.	IRIS, HEAST, or NCEA
TR	Target cancer risk	1E-05	NMED-specific value
THQ	Target hazard quotient	1	US EPA, 1989
BW	Body weight (kg)		
	-- adult	70	US EPA, 1989
	-- child	15	US EPA, 1991
AT	Averaging time (days)		
	-- carcinogens	25550	US EPA, 1989
	-- noncarcinogens	ED*365	
SA	Exposed surface area for soil/dust (cm^2/day)		US EPA, 1989
	– adult resident	5700	US EPA, 1996a
	– adult worker	3300	US EPA, 1996a
	-- child	2800	US EPA, 1989
AF	Adherence factor, soils (mg/cm^2)		US EPA, 1989
	– adult resident	0.07	US EPA, 1996a
	– adult worker	0.2	US EPA, 1996a
	-- child resident	0.2	US EPA, 1989
	– construction worker	0.3	NMED-specific value
ABS	Skin absorption defaults (unitless):		
	– semi-volatile organics	0.1	US EPA, 1989
	– volatile organics	na	US EPA, 2003a
	– inorganics	na	US EPA, 2000s
IRA	Inhalation rate (m^3/day)		
	-- adult resident	20	US EPA, 1991
	– adult worker	20	US EPA, 2001a
	-- child resident	10	Exposure Factors, (US EPA, 1997)
IRW	Drinking water ingestion rate (L/day)		
	-- adult	2.4	US EPA, 1997
	-- child	1.5	US EPA, 1997
IRS	Soil ingestion (mg/day)		
	-- adult residenti	100	US EPA, 1991
	-- child resident	200	US EPA, 1991
	-- commercial/industrial worker	100	US EPA, 2001a
	construction worker	330	US EPA, 1991
EF	Exposure frequency (days/yr)		
	-- residential	350	US EPA, 1991
	-- commercial/industrial	225	US EPA, 2001a
	– construction worker	250	NMED-specific value
ED	Exposure duration (years)		
	-- residential	30[a]	US EPA, 1991)
	-- child	6	(US EPA, 1991)
	-- commercial/industrial	25	(US EPA, 1999)
	– construction worker	1	NMED-specific value
	Age-adjusted factors for carcinogens		
IFSadj	Ingestion factor, soils ([mg-yr]/[kg-day])	114	US EPA, 2001a
SFSadj	Dermal factor, soils ([mg-yr]/[kg-day])	360	US EPA, 2001a
InhFadj	Inhalation factor, air ([m^3-yr]/[kg-day])	11	By analogy to RAGS: Part B, (US EPA, 1991)
IFWadj	Ingestion factor, water ([L-yr]/[kg-day])	1.1	By analogy to RAGS: Part B, (US EPA, 1991)
PEF	Particulate emission factor (m^3/kg)	Chem.-spec.	US EPA, 2001a
VFs	Volatilization factor for soil (m^3/kg)	Chem.-spec.	US EPA, 2001a
Csat	Soil saturation concentration (mg/kg)	Chem.-spec.	US EPA, 2001a

[a]Exposure duration for lifetime residents is assumed to be 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years).
Chem.-spec.- Chemical-specific value
na - not applicable
RAGS – Risk Assessment Guidance for Superfund
IRIS – Integrated Risk Information System, USEPA, 2003b
HEAST – Health Effects Assessment Summary Tables, USEPA, 1997
NCEA – National Center for Environmental Assessment, Office of Research and Development (USEPA, 2003c)
NMED – New Mexico Environment Department

APPENDIX B

Table B-1
Physical and Chemical Parameters

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Acenaphthene	154.21	1.6E-04	6.36E-03	4.21E-02	7.69E-06	7.08E+03	1.06E+01	4.24E+00	3.31E-07	2.09E+05	4.57E+01	X
Acetaldehyde	44	7.8E-05	3.20E-03	1.20E-01	1.40E-05	1.80E+01	2.70E-02	1.00E+06	2.68E-05	2.32E+04	1.95E+05	X
Acetone	58	3.9E-05	1.60E-03	1.24E-01	1.14E-05	5.80E-01	8.70E-04	1.00E+06	1.70E-05	2.91E+04	1.69E+05	X
Acrylonitrile	53	8.8E-05	3.60E-03	1.08E-01	1.34E-05	8.50E-01	1.28E-03	7.90E+04	3.12E-05	2.15E+04	1.34E+04	X
Acetophenone		1.1E-05	4.51E-04	6.00E-02	8.70E-06	3.09E+01	4.64E-02	6.10E+03	3.21E-06	6.71E+04	1.31E+03	X
Acrolein	56	1.2E-04	4.90E-03	1.05E-01	1.22E-05	2.10E+01	3.15E-02	2.10E+05	3.38E-05	2.07E+04	4.20E+04	X
Aldrin	365	1.7E-04	6.97E-03	1.32E-02	4.86E-06	2.45E+06	3.68E+03	1.80E-01				
Aluminum												
Anthracene	178	6.5E-05	2.67E-03	3.24E-02	7.74E-06	2.95E+04	4.43E+01	4.34E-02	3.08E-08	6.84E+05	1.93E+00	X
Antimony												
Arsenic												
Barium												
Benzene	78.1	5.6E-03	2.28E-01	8.80E-02	9.80E-06	5.89E+01	8.84E-02	1.75E+03	8.63E-04	4.09E+03	4.94E+02	X
Benzidine												
Benzo(a)anthracene	228	3.3E-06	1.37E-04	5.10E-02	9.00E-06	3.98E+05	5.97E+02	9.40E-03				
Benzo(a)pyrene	250	1.1E-06	4.63E-05	4.30E-02	9.00E-06	1.06E+06	1.59E+03	1.62E-03				
Benzo(b)fluoranthene	252.3	1.1E-04	4.55E-03	2.26E-02	5.56E-06	1.23E+06	1.85E+03	1.50E-03				
Benzo(k)fluoranthene	252.3	8.3E-07	3.40E-05	2.26E-02	5.56E-06	1.23E+06	1.85E+03	8.00E-04				
Beryllium												
α-BHC	290.85	1.1E-05	4.35E-04	1.42E-02	7.34E-06	1.23E+03	1.85E+00	2.00E+00				
β-BHC	290.85	7.4E-07	3.05E-05	1.42E-02	7.34E-06	1.26E+03	1.89E+00	2.40E-01				
γ-BHC	290.85	1.4E-05	5.74E-04	1.42E-02	7.34E-06	1.07E+03	1.61E+00	6.80E+00				
1,1-Biphenyl	150	2.9E-04	1.20E-02	4.00E-02	8.20E-06	7.80E+03	1.17E+01	7.50E+00	5.19E-07	1.67E+05	8.90E+01	X
Bis(2-chloroethyl) ether	140	1.8E-05	7.38E-04	6.92E-02	7.53E-06	1.55E+01	2.33E-02	1.72E+04	4.87E-06	5.45E+04	3.29E+03	X
Bis(2-chloroisopropyl) ether	170	1.1E-04	4.60E-03	6.30E-02	6.40E-06	6.17E+01	9.25E-02	1.70E+03	1.45E-05	3.15E+04	4.43E+02	X
Bis(2-ethylhexyl) phthalate		1.0E-07	4.18E-06	3.51E-02	3.66E-06	1.51E+07	2.27E+04	3.40E-01				
Bis(chloromethyl) ether	120	2.0E-04	8.20E-03	8.90E-02	9.40E-06	1.20E+00	1.80E-03	2.20E+04	5.42E-05	1.63E+04	3.75E+03	X
Boron												
Bromobenzene	MW<200	3.7E-03	1.50E-01	7.30E-02	8.70E-06	2.20E+02	3.30E-01	4.70E+02	2.59E-04	7.47E+03	2.42E+02	X

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Bromodichloromethane	164	1.6E-03	6.56E-02	2.98E-02	1.06E-05	5.50E+01	8.25E-02	6.74E+03	9.37E-05	1.24E+04	1.74E+03	X
Bromomethane	94.95	6.2E-03	2.56E-01	7.28E-02	1.21E-05	9.00E+00	1.35E-02	1.52E+04	1.07E-03	3.66E+03	3.21E+03	X
1,3-Butadiene	54	1.8E-01	7.30E+00	9.80E-02	1.10E-05	1.20E+02	1.80E-01	7.40E+02	7.27E-03	1.41E+03	8.85E+02	X
2-Butanone (MEK)	72	6.6E-07	2.70E-05	7.73E+03	8.47E-01	4.50E+00	6.75E-03	2.70E-02	2.14E-01	2.60E+02	4.71E-03	X
tert-Butyl methyl ether (MTBE)	88.2	5.9E-04	2.40E-02	8.00E-02	1.00E-05	6.00E+00	9.00E-03	3.60E-02	1.32E-04	1.05E+04	6.46E-03	X
n-Butylbenzene	130	1.3E-02	5.40E-01	7.50E-02	7.80E-06	2.80E+03	4.20E+00	1.40E+01	1.11E-04	1.14E+04	6.20E+01	X
sec-Butylbenzene	130	1.9E-02	7.70E-01	7.50E-02	7.80E-06	2.20E+03	3.30E+00	1.70E+01	1.97E-04	8.55E+03	6.05E+01	X
tert-Butylbenzene	130	1.3E-02	5.20E-01	7.50E-02	7.80E-06	2.20E+03	3.30E+00	3.00E+01	1.34E-04	1.04E+04	1.06E+02	X
Cadmium												
Carbon disulfide	76	2.9E-02	1.20E+00	1.04E-01	1.00E-05	4.60E+01	6.90E-02	1.19E+03	4.03E-03	1.89E+03	4.48E+02	X
Carbon tetrachloride	154	3.0E-02	1.25E+00	7.80E-02	8.80E-06	1.74E+02	2.61E-01	7.93E+02	2.06E-03	2.64E+03	4.55E+02	X
Chlordane	409.8	4.9E-05	1.99E-03	1.18E-02	4.37E-06	1.20E+05	1.80E+02	5.60E-02				
2-Chloroacetophenone	MW<200	3.7E-02	1.50E+00	7.20E-02	6.80E-06	3.30E+02	4.95E-01	4.70E+02	1.57E-03	3.03E+03	3.93E+02	X
2-Chloro-1,3-butadiene	88	3.2E-02	1.30E+00	1.10E-01	1.10E-05	5.00E+01	7.50E-02	7.40E+02	4.41E-03	1.81E+03	2.91E+02	X
1-Chloro-1,1-difluoroethane	MW<200	1.0E-01	4.10E+00	8.00E-02	1.10E-05	5.80E+01	8.70E-02	2.80E+02	5.45E-03	1.63E+03	2.05E+02	X
Chlorobenzene	113	3.7E-03	1.50E-01	7.30E-02	8.70E-06	2.19E+02	3.29E-01	4.72E+02	2.60E-04	7.46E+03	2.42E+02	X
1-Chlorobutane	MW<200	3.2E-02	1.30E+00	1.10E-01	1.10E-05	5.00E+01	7.50E-02	7.40E+02	4.41E-03	1.81E+03	2.91E+02	X
Chlorodifluoromethane	MW<200	1.0E-01	4.10E+00	8.00E-02	1.10E-05	5.80E+01	8.70E-02	2.80E+02	5.45E-03	1.63E+03	2.05E+02	X
Chloroethane	65	1.1E-02	4.50E-01	1.00E-01	1.20E-05	1.50E+01	2.25E-02	5.70E+03	2.25E-03	2.53E+03	1.38E+03	X
Chloroform	120	3.7E-03	1.50E-01	1.04E-01	1.00E-05	3.98E+01	5.97E-02	7.92E+03	7.75E-04	4.31E+03	1.94E+03	X
Chloromethane	51	2.4E-02	9.80E-01	1.09E-01	6.50E-06	3.50E+01	5.25E-02	8.20E+03	3.88E-03	1.93E+03	2.74E+03	X
β-Chloronaphthalene	160	3.2E-04	1.30E-02	3.50E-02	8.80E-06	1.60E+03	2.40E+00	1.20E+01	2.29E-06	7.94E+04	3.08E+01	X
o-Chloronitrobenzene	MW<200	2.4E-05	9.80E-04	7.60E-02	8.60E-06	6.50E+01	9.75E-02	2.10E+03	4.74E-06	5.52E+04	5.57E+02	X
p-Chloronitrobenzene	MW<200	2.4E-05	9.80E-04	7.60E-02	8.60E-06	6.50E+01	9.75E-02	2.10E+03	4.74E-06	5.52E+04	5.57E+02	X
2-Chlorophenol	130	3.9E-04	1.60E-02	5.01E-02	9.46E-06	4.00E+02	6.00E-01	2.02E+06	1.32E-05	3.31E+04	1.55E+06	X
2-Chloropropane	MW<200	2.3E-03	9.40E-02	8.00E-02	1.00E-05	5.10E+01	7.65E-02	2.70E+03	3.59E-04	6.34E+03	6.89E+02	X
o-Chlorotoluene	MW<200	3.4E-03	1.40E-01	7.20E-02	8.70E-06	1.60E+02	2.40E-01	4.70E+02	2.89E-04	7.06E+03	1.99E+02	X
Chromium III												
Chromium VI												
Chrysene	228.28	9.5E-05	3.88E-03	2.48E-02	6.21E-06	3.98E+05	5.97E+02	1.60E-03	2.38E-09	2.46E+06	9.55E-01	X
Cobalt												
Copper												

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Crotonaldehyde	MW<200	2.4E-01	1.00E+01	9.10E-02	1.00E-05	8.40E+02	1.26E+00	2.00E+01	4.27E-03	1.84E+03	5.18E+01	X
Cumene (isopropylbenzene)	120	1.1E-02	4.70E-01	7.50E-02	7.10E-06	2.20E+02	3.30E-01	6.10E+01	7.75E-04	4.31E+03	3.37E+01	X
Cyanide												
Cyanogen	52	5.1E-03	2.10E-01	9.60E-02	1.00E-05	2.60E+01	3.90E-02	8.50E+03	1.06E-03	3.69E+03	1.96E+03	X
Cyanogen bromide	52	5.1E-03	2.10E-01	9.60E-02	1.00E-05	2.60E+01	3.90E-02	8.50E+03	1.06E-03	3.69E+03	1.96E+03	X
Cyanogen chloride	52	5.1E-03	2.10E-01	9.60E-02	1.00E-05	2.60E+01	3.90E-02	8.50E+03	1.06E-03	3.69E+03	1.96E+03	X
DDD	320	4.0E-06	1.64E-04	1.69E-02	4.76E-06	1.00E+06	1.50E+03	9.00E-02				
DDE	318	2.1E-05	8.61E-04	1.44E-02	5.87E-06	4.47E+06	6.71E+03	1.20E-01				
DDT	354.5	8.1E-06	3.32E-04	1.37E-02	4.95E-06	2.63E+06	3.95E+03	2.50E-02				
Dibenz(a,h)anthracene	278.3	1.5E-08	6.0E-07	2.02E-02	5.18E-06	3.80E+06	5.70E+03	2.49E-03				
Dibenzofuran		1.3E-05	5.33E-04	6.01E-02	1.00E-05	7.76E+03	1.16E+01	3.10E+00	6.78E-08	4.61E+05	3.66E+01	X
1,2-Dibromo-3-chloropropane	240	1.5E-04	6.00E-03	2.10E-02	7.00E-06	2.80E+01	4.20E-02	1.20E+03	8.64E-06	4.09E+04	2.53E+02	X
Dibromochloromethane	210	8.5E-04	3.50E-02	9.60E-02	1.00E-05	4.70E+02	7.05E-01	4.40E+03	4.70E-05	1.75E+04	3.86E+03	X
1,2-Dibromoethane	188	3.2E-04	1.30E-02	7.33E-02	8.06E-06	2.80E+01	4.20E-02	3.40E+03	5.63E-05	1.60E+04	7.18E+02	X
1,4-Dichloro-2-butene	130	2.7E-04	1.10E-02	7.30E-02	8.10E-06	4.80E+01	7.20E-02	2.80E+03	4.18E-05	1.86E+04	6.75E+02	X
1,2-Dichlorobenzene	147	1.9E-03	7.79E-02	6.90E-02	7.90E-06	3.78E+02	5.67E-01	1.56E+02	8.82E-05	1.28E+04	1.16E+02	X
1,3-Dichlorobenzene	147	1.9E-03	7.80E-02	6.90E-02	7.90E-06	6.20E+02	9.30E-01	1.56E+02	5.93E-05	1.56E+04	1.73E+02	X
1,4-Dichlorobenzene	147	2.4E-03	9.96E-02	6.90E-02	7.90E-06	6.16E+02	9.24E-01	7.38E+01	7.59E-05	1.38E+04	8.14E+01	X
3,3-Dichlorobenzidine		4.0E-09	1.64E-07	1.94E-02	6.74E-06	7.24E+02	1.09E+00	3.11E+00				
Dichlorodifluoromethane	120	1.0E-01	4.10E+00	8.00E-02	1.05E-05	5.80E+01	8.70E-02	2.80E+02	5.45E-03	1.63E+03	2.05E+02	X
1,1-Dichloroethane	99	5.6E-03	2.30E-01	7.42E-02	1.05E-05	3.16E+01	4.74E-02	5.06E+03	8.58E-04	4.10E+03	1.22E+03	X
1,2-Dichloroethane	99	9.8E-04	4.01E-02	1.04E-01	9.90E-06	1.74E+01	2.61E-02	8.52E+03	2.57E-04	7.49E+03	1.69E+03	X
cis-1,2-Dichloroethene	97	4.1E-03	1.67E-01	7.36E-02	1.13E-05	3.55E+01	5.33E-02	3.50E+03	6.23E-04	4.81E+03	8.41E+02	X
trans-1,2-Dichloroethene	97	9.4E-03	3.85E-01	7.07E-02	1.19E-05	5.25E+01	7.88E-02	6.30E+03	1.14E-03	3.56E+03	1.83E+03	X
1,1-Dichloroethene	97	2.7E-02	1.10E+00	9.00E-02	1.00E-05	5.90E+01	8.85E-02	2.30E+03	3.13E-03	2.15E+03	8.83E+02	X
2,4-Dichlorophenol		3.2E-06	1.30E-04	3.46E-02	8.77E-06	1.47E+02	2.21E-01	4.50E+03				
1,2-Dichloropropane	110	2.7E-03	1.10E-01	7.80E-02	8.70E-06	4.40E+01	6.60E-02	2.80E+03	4.24E-04	5.83E+03	6.90E+02	X
1,3-Dichloropropene	111	1.8E-02	7.26E-01	6.26E-02	1.00E-05	4.57E+01	6.86E-02	2.80E+03	1.72E-03	2.89E+03	8.98E+02	X
Dicyclopentadiene	130	1.1E-02	4.40E-01	6.70E-02	1.00E-05	5.70E+02	8.55E-01	1.80E+03	3.34E-04	6.58E+03	1.93E+03	X
Dieldrin	381	1.5E-05	6.19E-04	1.25E-02	4.74E-06	2.14E+04	3.21E+01	1.95E-01				
Diethyl phthalate	222.2	4.5E-07	1.85E-05	2.56E-02	6.35E-06	2.88E+02	4.32E-01	1.08E+03				
Dimethyl phthalate	194.19	4.1E-07	1.70E-05									

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Di-n-butyl phthalate	278.34	9.4E-10	3.85E-08	4.38E-02	7.86E-06	3.39E+04	5.09E+01	1.12E+01				
2,4-Dimethylphenol		2.0E-06	8.20E-05	5.84E-02	8.69E-06	2.09E+02	3.14E-01	7.87E+03				
2,4-Dinitrotoluene	182.14	9.3E-08	3.80E-06	2.03E-01	7.06E-06	9.55E+01	1.43E-01	2.70E+02				
1,2-Diphenylhydrazine		4.6E-11	1.90E-09									
Endosulfan	406.95	1.1E-05	4.59E-04	1.15E-02	4.55E-06	2.14E+03	3.21E+00	5.10E-01				
Endrin	381	7.5E-06	3.08E-04	1.25E-02	4.74E-06	1.23E+04	1.85E+01	2.50E-01				
Epichlorohydrin	93	3.2E-05	1.30E-03	8.80E-02	9.80E-06	3.50E+00	5.25E-03	6.00E+04	1.04E-05	3.73E+04	1.04E+04	X
Ethyl acetate	88	1.4E-04	5.70E-03	7.30E-02	9.70E-06	5.90E+01	8.85E-02	8.00E+04	2.12E-05	2.61E+04	2.06E+04	X
Ethyl acrylate	MW<200	2.4E-01	9.80E+00	9.10E-02	8.60E-06	8.40E+02	1.26E+00	2.00E+01	4.22E-03	1.85E+03	5.13E+01	X
Ethyl chloride	65	1.1E-02	4.50E-01	1.00E-01	1.20E-05	1.50E+01	2.25E-02	5.70E+03	2.25E-03	2.53E+03	1.38E+03	X
Ethyl ether	MW<200	1.3E-05	5.30E-04	7.00E-02	9.30E-06	1.40E+01	2.10E-02	1.00E+04	4.41E-06	5.72E+04	1.89E+03	X
Ethyl methacrylate	MW<200	2.4E-01	1.00E+01	9.10E-02	8.60E-06	8.40E+02	1.26E+00	2.00E+01	4.27E-03	1.84E+03	5.18E+01	X
Ethylbenzene	106.2	7.9E-03	3.23E-01	7.50E-02	7.80E-06	3.63E+02	5.45E-01	1.69E+02	3.93E-04	6.06E+03	1.27E+02	X
Ethylene oxide	44	7.6E-05	3.10E-03	1.30E-01	1.50E-05	2.20E+00	3.30E-03	1.00E+06	3.21E-05	2.12E+04	1.71E+05	X
Fluoranthene	202.3	1.6E-05	6.60E-04	3.02E-02	6.35E-06	1.07E+05	1.61E+02	2.06E-01				
Fluorene	166.21	6.4E-05	2.61E-03	6.08E-02	7.88E-06	1.38E+04	2.07E+01	1.90E+00	1.08E-07	3.66E+05	3.96E+01	X
Furan	68	5.4E-03	2.20E-01	1.00E-01	1.20E-05	1.20E+01	1.80E-02	1.00E+04	1.27E-03	3.38E+03	2.11E+03	X
Heptachlor	373.5	1.1E-03	4.47E-02	1.12E-02	5.69E-06	1.41E+06	2.12E+03	1.80E-01				
Hexachlorobenzene		1.3E-03	5.41E-02	5.42E-02	5.91E-06	5.50E+04	8.25E+01	6.20E+00				
Hexachloro-1,3-butadiene		8.1E-03	3.34E-01	5.61E-02	6.16E-06	5.37E+04	8.06E+01	3.23E+00				
Hexachlorocyclopentadiene		2.7E-02	1.11E+00	1.61E-02	7.21E-06	2.00E+05	3.00E+02	1.80E+00				
Hexachloroethane		3.9E-03	1.59E-01	2.50E-03	6.80E-06	1.78E+03	2.67E+00	5.00E+01				
n-Hexane	86	1.2E-01	5.00E+00	2.00E-01	7.80E-06	8.90E+02	1.34E+00	1.80E+01	5.83E-03	1.57E+03	3.75E+01	X
HMX		1.0E-11	4.10E-10									
Hydrogen cyanide	27	1.3E-04	5.30E-03	1.80E-01	1.80E-05	1.70E+01	2.55E-02	1.00E+06	6.36E-05	1.51E+04	1.94E+05	X
Indeno(1,2,3-c,d)pyrene	276.3	1.6E-06	6.56E-05	1.90E-02	5.66E-06	3.47E+06	5.21E+03	2.20E-05				
Iron												
Isobutanol	74	1.2E-05	4.90E-04	8.60E-02	9.30E-06	6.20E+01	9.30E-02	8.50E+04	3.43E-06	6.49E+04	2.22E+04	X
Isophorone		6.6E-06	2.72E-04	6.23E-02	6.76E-06	4.68E+01	7.02E-02	1.20E+04				
Lead												
lead (Tetraethyl-)												
Maleic hydrazide	110	6.6E-03	2.70E-01	9.00E-02	1.10E-05	4.20E+01	6.30E-02	6.00E+03	1.13E-03	3.58E+03	1.57E+03	X

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Manganese												
Mercury (elemental)												
Mercury (methyl)		1.14E-02	4.67e-01									
Methacrylonitrile	MW<200	8.8E-05	3.60E-03	1.10E-01	1.30E-05	8.40E-01	1.26E-03	7.90E+04	3.15E-05	2.14E+04	1.34E+04	X
Methomyl	160	3.9E-02	1.60E+00	6.90E-02	1.00E-05	1.50E+01	2.25E-02	1.70E+05	3.57E-03	2.01E+03	6.39E+04	X
Methyl acetate	MW<200	2.0E-05	8.40E-04	1.00E-01	1.00E-05	2.20E+00	3.30E-03	1.00E+06	8.36E-06	4.15E+04	1.71E+05	X
Methyl acrylate	MW<200	2.4E-01	9.80E+00	9.10E-02	8.60E-06	8.40E+02	1.26E+00	6.00E+01	4.22E-03	1.85E+03	1.54E+02	X
Methyl isobutyl ketone	100	1.4E-04	5.70E-03	7.50E-02	7.80E-06	1.30E+02	1.95E-01	1.90E+04	1.52E-05	3.08E+04	6.90E+03	X
Methyl methacrylate	100	3.4E-04	1.40E-02	7.70E-02	8.60E-06	1.30E+01	1.95E-02	1.50E+04	7.12E-05	1.42E+04	2.83E+03	X
Methyl styrene (alpha)	MW<200	2.3E-03	9.40E-02	7.10E-02	8.00E-06	3.60E+02	5.40E-01	3.00E+02	1.13E-04	1.13E+04	2.16E+02	X
Methyl styrene (mixture)	MW<200	2.3E-03	9.40E-02	7.10E-02	8.00E-06	3.60E+02	5.40E-01	3.00E+02	1.13E-04	1.13E+04	2.16E+02	X
Methylcyclohexane	98	4.4E-01	1.80E+01	7.00E-02	9.00E-06	2.20E+02	3.30E-01	1.40E+01	5.91E-03	1.56E+03	3.62E+01	X
Methylene bromide	170	9.0E-04	3.70E-02	9.60E-02	1.00E-05	2.50E+01	3.75E-02	1.20E+04	2.08E-04	8.33E+03	2.51E+03	X
Methylene chloride	85	2.2E-03	9.00E-02	1.00E-01	1.20E-05	1.20E+01	1.80E-02	1.30E+04	5.59E-04	5.08E+03	2.55E+03	X
Molybdenum												
Naphthalene	128.16	4.8E-04	1.98E-02	5.90E-02	7.50E-06	2.00E+03	3.00E+00	3.10E+01	4.57E-06	5.62E+04	9.83E+01	X
Nickel												
Nitrate												
Nitrite												
Nitrobenzene	120	2.4E-05	9.84E-04	7.60E-02	8.60E-06	6.46E+01	9.69E-02	2.10E+03	4.77E-06	5.50E+04	5.56E+02	X
Nitroglycerin		6.1E-03	2.50E-01			2.60E+02	3.90E-01	1.80E+03				
N-Nitrosodiethylamine		3.7E-06	1.50E-04			1.20E+03	1.80E+00					
N-Nitrosodimethylamine		1.4E-01	5.90E+00			1.20E+03	1.80E+00					
N-Nitrosodi-*n*-butylamine	160	3.2E-04	1.31E-02	5.80E-02	9.72E-06	2.60E+02	3.90E-01	1.30E+03	1.72E-05	2.89E+04	7.27E+02	X
N-Nitrosodiphenylamine	198.23	5.0E-06	2.05E-04	3.12E-02	6.35E-06	1.29E+03	1.94E+00	3.51E+01				
N-Nitrosopyrrolidine		4.9E-08	2.00E-06			1.90E+01	2.85E-02					
m-Nitrotoluene	MW<200	2.4E-05	9.80E-04	7.60E-02	8.60E-06	6.50E+01	9.75E-02	2.10E+03	4.74E-06	5.52E+04	5.57E+02	X
o-Nitrotoluene	MW<200	2.4E-05	9.80E-04	7.60E-02	8.60E-06	6.50E+01	9.75E-02	2.10E+03	4.74E-06	5.52E+04	5.57E+02	X
p-Nitrotoluene	MW<200	2.4E-05	9.80E-04	7.60E-02	8.60E-06	6.50E+01	9.75E-02	2.10E+03	4.74E-06	5.52E+04	5.57E+02	X
Pentachlorobenzene		7.1E-03	2.90E-01									
Pentachlorophenol		2.4E-08	1.00E-06	5.60E-02	6.10E-06	5.92E+02	8.88E-01	1.95E+03				
Phenanthrene	178.2	2.3E-05	9.40E-04			1.40E+04	2.10E+01					

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
Phenol	94	4.0E-07	1.63E-05	8.20E-02	9.10E-06	2.88E+01	4.32E-02	8.28E+04				
Polychlorinatedbiphenyls												
Aroclor 1016		4.23E-02	1.73E+00									
Aroclor 1221		1.8E-08	7.40E-07									
Aroclor 1232		1.8E-08	7.40E-07									
Aroclor 1242		1.8E-08	7.40E-07									
Aroclor 1248	375.7	1.8E-08	7.40E-07	5.70E+03	6.00E-01	5.30E+05	7.95E+02					
Aroclor 1254	375.7	1.8E-08	7.40E-07	5.70E+03	6.00E-01	5.30E+05	7.95E+02					
Aroclor 1260	375.7	1.8E-08	7.40E-07	5.70E+03	6.00E-01	5.30E+05	7.95E+02					
n-Propylbenzene	MW<200	1.3E-02	5.40E-01	7.50E-02	7.80E-06	2.80E+03	4.20E+00	1.20E+01	1.11E-04	1.14E+04	5.32E+01	X
Propylene oxide	58	8.5E-05	3.50E-03	1.20E-01	1.30E-05	2.50E+01	3.75E-02	4.80E+05	2.74E-05	2.29E+04	9.87E+04	X
Pyrene	200	1.1E-05	4.51E-04	2.72E-02	7.24E-06	1.05E+05	1.58E+02	1.35E-01	2.83E-09	2.26E+06	2.13E+01	X
RDX		6.3E-08	2.60E-06			7.00E+01	1.05E-01					
Selenium												
Silver												
Strontium												
Styrene	100	2.7E-03	1.10E-01	7.10E-02	8.00E-06	7.80E+02	1.17E+00	3.10E+02	7.05E-05	1.43E+04	4.19E+02	X
1,2,4,5-Tetrachlorobenzene		1.0E-03	4.10E-02									
1,1,1,2-Tetrachloroethane		3.4E-04	1.41E-02	7.10E-02	7.90E-06	7.90E+01	1.19E-01	2.97E+03	4.33E-05	1.82E+04	8.55E+02	X
1,1,2,2-Tetrachloroethane	170	3.4E-04	1.40E-02	7.10E-02	7.90E-06	9.33E+01	1.40E-01	2.97E+03	4.01E-05	1.90E+04	9.19E+02	X
Tetrachloroethene	170	1.8E-02	7.54E-01	7.20E-02	8.20E-06	1.55E+02	2.33E-01	2.00E+02	1.35E-03	3.27E+03	9.76E+01	X
Thallium												
Toluene	92	6.6E-03	2.72E-01	8.70E-02	8.60E-06	1.82E+02	2.73E-01	5.26E+02	6.09E-04	4.87E+03	2.48E+02	X
Toxaphene		6.0E-06	2.46E-04	1.16E-02	4.34E-06	2.57E+05	3.86E+02	7.40E-01				
Tribromomethane		6.6E-04	2.70E-02									
1,1,2-Trichloro-1,2,2-trifluoroethane		5.2E-01	2.14E+01	2.88E-02	8.07E-06	1.60E+02	2.40E-01	1.10E+03	2.59E-03	2.36E+03	3.18E+03	X
1,2,4-Trichlorobenzene	181	1.4E-03	5.82E-02	3.00E-02	8.23E-06	1.78E+03	2.67E+00	3.00E+02	7.57E-06	4.37E+04	8.53E+02	X
1,1,1-Trichloroethane	130	1.7E-02	7.05E-01	7.80E-02	8.80E-06	1.10E+02	1.65E-01	1.33E+03	1.61E-03	2.99E+03	5.51E+02	X
1,1,2-Trichloroethane	133	9.1E-04	3.74E-02	7.80E-02	8.80E-06	5.01E+01	7.52E-02	4.42E+03	1.45E-04	9.99E+03	1.09E+03	X
Trichloroethene	131	1.0E-02	4.22E-01	7.90E-02	9.10E-06	1.66E+02	2.49E-01	1.10E+03	8.70E-04	4.07E+03	5.12E+02	X
Trichlorofluoromethane	140	9.8E-02	4.00E+00	8.70E-02	1.30E-05	1.60E+02	2.40E-01	1.10E+03	4.84E-03	1.73E+03	9.59E+02	X
2,4,5-Trichlorophenol	197.46	4.4E-06	1.80E-04									

Chemical	MW (g/mole)	H (atm-m^3/mole)	H' (dimension-less)	D_a (cm^2/s)	D_w (cm^2/s)	K_{oc} (cm^3/g)	K_d (cm^3/g)	S (mg/L-water)	D_A (cm^2/s)	VF (m^3/kg)	SAT (mg/kg)	VOC
2,4,6-Trichlorophenol	197.46	7.8E-06	3.20E-04									
1,1,2-Trichloropropane	150	2.9E-02	1.20E+00	4.00E-02	9.30E-06	5.10E+01	7.65E-02	2.70E+04	1.52E-03	3.08E+03	1.04E+04	X
1,2,3-Trichloropropane	150	2.7E-02	1.10E+00	7.10E-02	7.90E-06	5.10E+01	7.65E-02	2.70E+04	2.55E-03	2.38E+03	1.00E+04	X
1,2,3-Trichloropropene	MW<200	2.7E-02	1.10E+00	7.10E-02	7.90E-06	5.10E+01	7.65E-02	2.70E+04	2.55E-03	2.38E+03	1.00E+04	X
Triethylamine	MW<200	9.0E-05	3.70E-03	1.20E-01	1.30E-05	2.20E+00	3.30E-03	1.00E+06	3.46E-05	2.04E+04	1.71E+05	X
1,2,4-Trimethylbenzene	120	5.6E-03	2.30E-01	7.50E-02	7.10E-06	3.70E+03	5.55E+00	5.70E+01	3.65E-05	1.99E+04	3.27E+02	X
1,3,5-Trimethylbenzene	120	7.8E-03	3.20E-01	7.50E-02	7.10E-06	8.20E+02	1.23E+00	4.80E+01	2.03E-04	8.43E+03	6.89E+01	X
2,4,6-Trinitrotoluene		4.6E-07	1.90E-05			1.60E+03	2.40E+00					
Vanadium												
Vinyl acetate	86	5.1E-04	2.10E-02	8.50E-02	9.20E-06	5.30E+00	7.95E-03	2.00E+04	1.24E-04	1.08E+04	3.56E+03	X
Vinyl bromide	MW<200	6.3E-03	2.60E-01	1.00E-01	1.20E-05	1.30E+02	1.95E-01	1.80E+04	8.05E-04	4.23E+03	7.07E+03	X
Vinyl chloride	63	2.7E-02	1.11E+00	1.10E-01	1.20E-06	1.86E+01	2.79E-02	2.80E+03	4.57E-03	1.78E+03	9.09E+02	X
Vinyl chloride	63	2.7E-02	1.11E+00	1.10E-01	1.20E-06	1.86E+01	2.79E-02	2.80E+03	4.57E-03	1.78E+03	9.09E+02	X
m-Xylene	106	7.3E-03	3.01E-01	7.00E-02	7.80E-06	1.96E+02	2.94E-01	1.61E+02	5.16E-04	5.29E+03	8.00E+01	X
o-Xylene	106	5.2E-03	2.13E-01	8.70E-02	1.00E-05	2.41E+02	3.62E-01	1.78E+02	4.07E-04	5.96E+03	9.86E+01	X
p-Xylene	106	7.7E-03	3.14E-01	7.69E-02	8.44E-06	3.11E+02	4.67E-01	1.85E+02	4.38E-04	5.74E+03	1.24E+02	X
Xylenes	106	7.3E-03	3.00E-01	7.00E-02	7.80E-06	4.10E+02	6.15E-01	1.61E+02	3.12E-04	6.80E+03	1.32E+02	X
Zinc												

MW – Molecular weight
H – Henry's Law Constant
H' – Dimensionless Henry's Law Constant
D_a – Diffusivity in air
D_w – Diffusivity in water
K_{oc} – Soil organic carbon partition coefficient
K_d – Soil-water partition coefficient
S - Solubility in water
D_A – Apparent diffusivity (calculated for VOCs only)
VF – Volatilization factor (calculated for VOCs only)
SAT – Soil saturation limit (calculated for VOCs only)
VOC – Volatile organic compound

APPENDIX C

Table C-1
Human Health Benchmarks Used in Estimating SSLs

Chemical	SF_o (mg/kg-day^{-1}	Reference	RfD_o (mg/kg-day)	Reference	SF_i (mg/kg-day)$^{-1}$	Reference	RfD_i (mg/kg-day)	Reference	ABS
Acenaphthene			6.00E-02	IRIS			6.00E-02	r	0
Acetaldehyde					7.70E-03	IRIS	2.60E-03	IRIS	0
Acetone			9.00E-01	IRIS					0
Acrylonitrile	5.40E-01	IRIS	1.00E-03	HEAST	2.40E-01	IRIS	5.71E-04	IRIS	0
Acetophenone			1.00E-01	IRIS			1.00E-01	r	0
Acrolein			5.00E-04	IRIS			5.71E-06	IRIS	0
Aldrin	1.72E+01	IRIS	3.00E-05	IRIS	1.72E+01	IRIS	3.00E-05	r	0.1
Aluminum			1.00E+00	NCEA			1.40E-03	NCEA	0
Anthracene			3.00E-01	IRIS			3.00E-01	r	0
Antimony			4.00E-04	IRIS					0
Arsenic	1.50E+00	IRIS	3.00E-04	IRIS	1.51E+01	IRIS			0.03
Barium			7.00E-02	IRIS			1.43E-04	HEAST	0
Benzene	5.50E-02	IRIS	4.00E-03	IRIS	7.70E-03	IRIS	8.60E-03	IRIS	0
Benzidine	2.30E+02	IRIS	3.00E-03	IRIS	2.35E+02	IRIS			0.1
Benzo(a)anthracene	7.30E-01	NCEA							0.13
Benzo(a)pyrene	7.30E+00	IRIS							0.13
Benzo(b)fluoranthene	7.30E-01	NCEA							0.13
Benzo(k)fluoranthene	7.30E-02	NCEA							0.13
Beryllium			2.00E-03	IRIS	8.40E+00	IRIS	5.71E-06	IRIS	0
α-BHC	6.30E+00	IRIS	5.00E-04	NCEA	6.30E+00	IRIS	5.00E-04	r	0.04
β-BHC	1.80E+00	IRIS	2.00E-04	NCEA	1.80E+00	IRIS	2.00E-04	r	0.04
γ-BHC	1.30E+00	HEAST	3.00E-04	IRIS			3.00E-04	r	0.04
1,1-Biphenyl			5.00E-02	IRIS			5.00E-02	r	0
Bis(2-chloroethyl) ether	1.10E+00	IRIS			1.16E+00	IRIS			0
Bis(2-chloroisopropyl) ether			4.00E-02	IRIS			4.00E-02	r	0
Bis(2-ethylhexyl) phthalate	1.40E-02	IRIS	2.00E-02	IRIS			2.00E-02	r	0.1
Bis(chloromethyl) ether	2.20E+02	IRIS			2.17E+02	IRIS			0
Boron			9.00E-02	IRIS					0.1
Bromobenzene			2.00E-02	NCEA			2.90E-03	NCEA	0

Bromodichloromethane	6.20E-02	IRIS	2.00E-02	IRIS			2.00E-02	r	0
Bromomethane			1.40E-03	IRIS			1.43E-03	IRIS	0
1,3-Butadiene					1.05E-01	IRIS	5.71E-04	IRIS	0
2-Butanone (MEK)			6.00E-01	IRIS			1.43E+00	IRIS	0
tert-Butyl methyl ether (MTBE)	3.30E-03	NCEA			3.50E-04	NCEA	8.57E-01	IRIS	0
n-Butylbenzene			4.00E-02	NCEA			4.00E-02	r	0
sec-Butylbenzene			4.00E-02	NCEA			4.00E-02	r	0
tert-Butylbenzene			4.00E-02	NCEA			4.00E-02	r	0
Cadmium			1.00E-03	IRIS	6.30E+00	IRIS			0.001
Carbon disulfide			1.00E-01	IRIS			2.45E+00	IRIS	0
Carbon tetrachloride	1.30E-01	IRIS	7.00E-04	IRIS	5.25E-02	IRIS	7.00E-04	r	0
Chlordane	3.50E-01	IRIS	5.00E-04	IRIS	3.50E-01	IRIS	2.00E-04	IRIS	0.04
2-Chloroacetophenone							8.57E-06	IRIS	0
2-Chloro-1,3-butadiene			2.00E-02	HEAST			2.00E-03	HEAST	0
1-Chloro-1,1-difluoroethane							1.43E+01	IRIS	0
Chlorobenzene			2.00E-02	IRIS			1.70E-02	NCEA	0
1-Chlorobutane			4.00E-01	HEAST			4.00E-01	r	0
Chlorodifluoromethane							1.43E+01	IRIS	0
Chloroethane	2.90E-03	NCEA	4.00E-01	NCEA			2.86E+00	IRIS	0
Chloroform			1.00E-02	IRIS	8.05E-02	IRIS	8.60E-04	NCEA	0
Chloromethane	1.30E-02	HEAST			6.30E-03	HEAST	2.57E-02	IRIS	0
β-Chloronaphthalene			8.00E-02	IRIS			8.00E-02	r	0
o-Chloronitrobenzene	9.70E-03	HEAST	1.00E-03	HEAST			2.00E-05	HEAST	0
p-Chloronitrobenzene	6.70E-03	HEAST	1.00E-03	HEAST			1.70E-04	HEAST	0
2-Chlorophenol			5.00E-03	IRIS			5.00E-03	r	0
2-Chloropropane							2.90E-02	HEAST	0
o-Chlorotoluene			2.00E-02	IRIS			2.00E-02	r	0
Chromium III			1.50E+00	IRIS					0
Chromium VI			3.00E-03	IRIS	4.20E+01	IRIS	2.85E-05	IRIS	0
Chrysene	7.30E-03	NCEA							0.13
Cobalt			2.00E-02	NCEA	9.80E+00	NCEA	5.70E-06	NCEA	0
Copper			4.00E-02	HEAST					0
Crotonaldehyde	1.90E+00	HEAST							0
Cumene (isopropylbenzene)			1.00E-01	IRIS			1.14E-01	IRIS	0
Cyanide			2.00E-02	IRIS					0

Cyanogen			4.00E-02	IRIS			4.00E-02	r	0
Cyanogen bromide			9.00E-02	IRIS			9.00E-02	r	0
Cyanogen chloride			5.00E-02	IRIS			5.00E-02	r	0
DDD	2.40E-01	IRIS							0.03
DDE	3.40E-01	IRIS							0.03
DDT	3.40E-01	IRIS	5.00E-04	IRIS	3.40E-01	IRIS	5.00E-04	r	0.03
Dibenz(a,h)anthracene	7.30E+00	NCEA							0.13
Dibenzofuran			4.00E-03	NCEA			4.00E-03	r	0
1,2-Dibromo-3-chloropropane	1.40E+00	HEAST					5.70E-05	IRIS	0
Dibromochloromethane	8.40E-02	IRIS	2.00E-02	IRIS			2.00E-02	r	0
1,2-Dibromoethane	8.50E+01	IRIS			7.70E-01	IRIS	5.70E-05	HEAST	0
1,4-Dichloro-2-butene					9.30E+00	HEAST			0
1,2-Dichlorobenzene			9.00E-02	IRIS			5.71E-02	HEAST	0
1,3-Dichlorobenzene			9.00E-04	NCEA			9.00E-04	r	0
1,4-Dichlorobenzene	2.40E-02	HEAST	3.00E-02	NCEA	2.20E-02	NCEA	2.29E-01	IRIS	0
3,3-Dichlorobenzidine	4.50E-01	IRIS							0.1
Dichlorodifluoromethane			2.00E-01	IRIS			5.71E-02	HEAST	0
1,1-Dichloroethane			1.00E-01	HEAST			1.43E-01	HEAST	0
1,2-Dichloroethane	9.10E-02	IRIS	3.00E-02	NCEA	9.10E-02	IRIS	1.40E-03	NCEA	0
cis-1,2-Dichloroethene			1.00E-02	HEAST			1.00E-02	r	0
trans-1,2-Dichloroethene			2.00E-02	IRIS			2.00E-02	r	0
1,1-Dichloroethene			5.00E-02	IRIS			5.70E-02	IRIS	0
2,4-Dichlorophenol			3.00E-03	IRIS			3.00E-03	r	0.1
1,2-Dichloropropane	6.80E-02	HEAST					1.10E-03	IRIS	0
1,3-Dichloropropene	1.00E-01	IRIS	3.00E-02	IRIS	1.40E-02	IRIS	5.71E-03	IRIS	0
Dicyclopentadiene			3.00E-02	HEAST			5.71E-05	HEAST	0
Dieldrin	1.60E+01	IRIS	5.00E-05	IRIS	1.61E+01	IRIS	5.00E-05	r	0.1
Diethyl phthalate			8.00E-01	IRIS			8.00E-01	r	0.1
Dimethyl phthalate			1.00E+01	HEAST			1.00E+01	r	0.1
Di-n-butyl phthalate			1.00E-01	IRIS			1.00E-01	r	0.1
2,4-Dimethylphenol			2.00E-02	IRIS			2.00E-02	r	0.1
2,4-Dinitrotoluene			2.00E-03	IRIS			2.00E-03	r	0.1
1,2-Diphenylhydrazine	8.00E-01	IRIS			7.70E-01	IRIS			0.1
Endosulfan			6.00E-03	IRIS			6.00E-03	r	0.1
Endrin			3.00E-04	IRIS			3.00E-04	r	0.1

Epichlorohydrin	9.90E-03	IRIS	2.00E-03	HEAST	4.20E-03	IRIS	2.86E-04	IRIS	0
Ethyl acetate			9.00E-01	IRIS			9.00E-01	r	0
Ethyl acrylate	4.80E-02	HEAST							0
Ethyl chloride	2.90E-03	NCEA	4.00E-01	NCEA			2.86E+00	IRIS	0
Ethyl ether			2.00E-01	IRIS			2.00E-01	r	0
Ethyl methacrylate			9.00E-02	HEAST			9.00E-02	r	0
Ethylbenzene			1.00E-01	IRIS	3.80E-05	NCEA	2.90E-01	IRIS	0
Ethylene oxide	1.00E+00	HEAST			3.50E-01	HEAST			0
Fluoranthene			4.00E-02	IRIS			4.00E-02	r	0.13
Fluorene			4.00E-02	IRIS			4.00E-02	r	0
Furan			1.00E-03	IRIS			1.00E-03	r	0
Heptachlor	4.50E+00	IRIS	5.00E-04	IRIS	4.55E+00	IRIS	5.00E-04	r	0.1
Hexachlorobenzene	1.60E+00	IRIS	8.00E-04	IRIS	1.61E+00	IRIS	8.00E-04	r	0.1
Hexachloro-1,3-butadiene	7.80E-02	IRIS	2.00E-04	HEAST	7.70E-02	IRIS	2.00E-04	r	0.1
Hexachlorocyclopentadiene			6.00E-03	IRIS			5.71E-05	IRIS	0.1
Hexachloroethane	1.40E-02	IRIS	1.00E-03	IRIS	1.40E-02	IRIS	1.00E-03	r	0.1
n-Hexane			6.00E-02	HEAST			5.71E-02	IRIS	0
HMX			5.00E-02	IRIS			5.00E-02	r	0.1
Hydrogen cyanide			2.00E-02	IRIS			8.57E-04	IRIS	0
Indeno(1,2,3-c,d)pyrene	7.30E-01	NCEA							0.13
Iron			3.00E-01	NCEA					0
Isobutanol			3.00E-01	IRIS			3.00E-01	r	0
Isophorone	9.50E-04	IRIS	2.00E-01	IRIS			2.00E-01	r	0.1
Lead									0
Lead (tetraethyl-)			1.00E-07	IRIS					0.1
Maleic hydrazide			5.00E-01	IRIS			5.00E-01	r	0
Manganese			2.00E-02	IRIS			1.40E-05	IRIS	0
Mercury (elemental)			3.00E-04	HEAST			8.57E-05	IRIS	0
Mercury (methyl)			1.00E-04	IRIS					0.1
Methacrylonitrile			1.00E-04	IRIS			2.00E-04	HEAST	0
Methomyl			2.50E-02	IRIS			2.50E-02	r	0
Methyl acetate			1.00E+00	HEAST			1.00E+00	r	0
Methyl acrylate			3.00E-02	HEAST			3.00E-02	r	0
Methyl isobutyl ketone			8.00E-02	HEAST			8.57E-01	IRIS	0
Methyl methacrylate			1.40E+00	IRIS			2.00E-01	IRIS	0

Methyl styrene (alpha)			7.00E-02	HEAST			7.00E-02	r	0
Methyl styrene (mixture)			6.00E-03	HEAST			1.00E-02	HEAST	0
Methylcyclohexane							8.60E-01	HEAST	0
Methylene bromide			1.00E-02	HEAST			1.00E-02	r	0
Methylene chloride	7.50E-03	IRIS	6.00E-02	IRIS	1.65E-03	IRIS	8.60E-01	HEAST	0
Molybdenum			5.00E-03	IRIS					0
Naphthalene			2.00E-02	IRIS			8.57E-04	IRIS	0
Nickel			2.00E-02	IRIS			5.70E-05	ATSDR	0
Nitrate			1.60E+00	IRIS					0
Nitrite			1.00E-01	IRIS					0
Nitrobenzene			5.00E-04	IRIS			5.71E-04	HEAST	0
Nitroglycerin	1.40E-02	NCEA							0.1
N-Nitrosodiethylamine	1.50E+02	IRIS			1.51E+02	IRIS			0.1
N-Nitrosodimethylamine	5.10E+01	IRIS			4.90E+01	IRIS			0.1
N-Nitrosodi-*n*-butylamine	5.40E+00	IRIS			5.60E+00	IRIS			0.1
N-Nitrosodiphenylamine	4.90E-03	IRIS							0.1
N-Nitrosopyrrolidine	2.10E+00	IRIS			2.14E+00	IRIS			0.1
m-Nitrotoluene			1.00E-02	HEAST			1.00E-02	r	0
o-Nitrotoluene			1.00E-02	HEAST			1.00E-02	r	0
p-Nitrotoluene			1.00E-02	HEAST			1.00E-02	r	0
Pentachlorobenzene			8.00E-04	IRIS			8.00E-04	r	0.1
Pentachlorophenol	1.20E-01	IRIS	3.00E-02	IRIS			3.00E-02	r	0.25
Phenanthrene			3.00E-02	IRIS/pyrene			3.00E-02	r	0.1
Phenol			3.00E-01	IRIS			3.00E-01	r	0.1
Polychlorinatedbiphenyls									
Aroclor 1016	2.00E+00	IRIS	7.00E-05	IRIS	3.50E-01	IRIS	7.00E-05	r	0.14
Aroclor 1221	2.00E+00	IRIS			3.50E-01	IRIS			0.14
Aroclor 1232	2.00E+00	IRIS			3.50E-01	IRIS			0.14
Aroclor 1242	2.00E+00	IRIS			3.50E-01	IRIS			0.14
Aroclor 1248	2.00E+00	IRIS			3.50E-01	IRIS			0.14
Aroclor 1254	2.00E+00	IRIS	2.00E-05	IRIS	3.50E-01	IRIS	2.00E-05	r	0.14
Aroclor 1260	2.00E+00	IRIS			3.50E-01	IRIS			0.14
n-Propylbenzene			4.00E-02	NCEA			4.00E-02	r	0
Propylene oxide	2.40E-01	IRIS			1.30E-02	IRIS	8.57E-03	IRIS	0
Pyrene			3.00E-02	IRIS			3.00E-02	r	0

RDX	1.10E-01	IRIS	3.00E-03	IRIS			3.00E-03	r	0.1
Selenium			5.00E-03	IRIS					0
Silver			5.00E-03	IRIS					0
Strontium			6.00E-01	IRIS					0
Styrene			2.00E-01	IRIS			2.86E-01	IRIS	0
1,2,4,5-Tetrachlorobenzene			3.00E-04	IRIS			3.00E-04	r	0.1
1,1,1,2-Tetrachloroethane	2.60E-02	IRIS	3.00E-02	IRIS	2.59E-02	IRIS	3.00E-02	r	0
1,1,2,2-Tetrachloroethane	2.00E-01	IRIS	6.00E-02	NCEA	2.03E-01	IRIS	6.00E-02	r	0
Tetrachloroethene	5.20E-02	NCEA	1.00E-02	IRIS	2.03E-02	NCEA	1.14E-01	NCEA	0
Thallium			6.60E-05	IRIS					0
Toluene			2.00E-01	IRIS			1.10E-01	HEAST	0
Toxaphene	1.10E+00	IRIS			1.12E+00	IRIS			0.1
Tribromomethane	7.90E-03	IRIS	2.00E-02	IRIS	3.85E-03	IRIS	2.00E-02	r	0
1,1,2-Trichloro-1,2,2-trifluoroethane			3.00E+01	IRIS			8.57E+00	HEAST	0
1,2,4-Trichlorobenzene			1.00E-02	IRIS			5.70E-02	HEAST	0
1,1,1-Trichloroethane			2.80E-01	NCEA			6.30E-01	NCEA	0
1,1,2-Trichloroethane	5.70E-02	IRIS	4.00E-03	IRIS	5.60E-02	IRIS	4.00E-03	r	0
Trichloroethene	4.0E-01	NCEA	3.00E-04	NCEA	4.0E-01	NCEA	1.00E-02	NCEA	0
Trichlorofluoromethane			3.00E-01	IRIS			2.00E-01	HEAST	0
2,4,5-Trichlorophenol			1.00E-01	IRIS			1.00E-01	r	0.1
2,4,6-Trichlorophenol	1.10E-02	IRIS	1.00E-04	NCEA	1.09E-02	IRIS	1.00E-04	r	0.1
1,1,2-Trichloropropane			5.00E-03	IRIS			5.00E-03	r	0
1,2,3-Trichloropropane	2.00E+00	NCEA	6.00E-03	IRIS			1.40E-03	NCEA	0
1,2,3-Trichloropropene			5.00E-03	HEAST			5.00E-03	r	0
Triethylamine							1.99E-03	IRIS	0
1,2,4-Trimethylbenzene			5.00E-02	NCEA			1.70E-03	NCEA	0
1,3,5-Trimethylbenzene			5.00E-02	NCEA			1.70E-03	NCEA	0
2,4,6-Trinitrotoluene	3.00E-02	IRIS	5.00E-04	IRIS			5.00E-04	r	0.1
Vanadium			7.00E-03	HEAST					0
Vinyl acetate			1.00E+00	HEAST			5.71E-02	IRIS	0
Vinyl bromide			1.10E-01	HEAST			8.57E-04	IRIS	0
Vinyl chloride (Child)	1.40E+00	IRIS	3.00E-03	IRIS	3.00E-02	IRIS	2.80E-02	IRIS	0
Vinyl chloride (Adult)	7.20E-01	IRIS	3.00E-03	IRIS	1.54E-02	IRIS	2.85E-02	IRIS	0
m-Xylene			2.00E-01	IRIS			2.86E-02	IRIS	0.1
o-Xylene			2.00E-01	IRIS			2.86E-02	IRIS	0.1

p-Xylene			2.00E-01	IRIS			2.86E-02	IRIS	0.1
Xylenes			2.00E-01	IRIS			2.86E-02	IRIS	0.1
Zinc			3.00E-01	IRIS					0

SF_o – Oral cancer slope factor
SF_i – Inhalation cancer slope factor
RfD_o – Oral Reference Dose
RfD_i – Inhalation Reference Dose
ABS – Dermal absorption coefficient

IRIS – Integrated Risk Information System, USEPA 2003b
HEAST – Health Effects Assessment Summary Tables, USEPA 1997
NCEA – National Center for Environmental Assessment, Office of Research and Development (USEPA 2003c)
r – Route-to-route extrapolation

VOLUME 2

TIER 1: SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

PHASE I

Scoping Assessment

TABLE OF CONTENTS

1. Introduction 1

2. Scoping Assessment 2
   - 2.1 Compile and Assess Basic Site Information 2
   - 2.2 Site Visit 3
   - 2.3 Identify Contaminants of Potential Ecological Concern 4
   - 2.4 Developing the Preliminary Conceptual Site Exposure Model 4
   - 2.5 Assembling the Scoping Assessment Report6

3. Site Exclusion Criteria 9

4. Technical Decision Point: Is Ecological Risk Suspected? 9

1. Introduction

The purpose of an ecological risk assessment is to evaluate the potential adverse effects that chemical contamination has on the plants and animals that make up ecosystems. The risk assessment process provides a way to develop, organize and present scientific information so that it is relevant to environmental decisions.

The New Mexico Environment Department Hazardous Waste Bureau (NMED) has developed a tiered procedure for the evaluation of ecological risk. This procedure is outlined in the *Guidance for Assessing Ecological Risks Posed by Chemicals: Screening-Level Ecological Risk Assessment* (GAERPC) (NMED, 2000). Briefly, the tiers of the procedure are organized as follows:

PHASE I: QUALITATIVE ASSESSMENT

- Tier I: Screening-Level Ecological Risk Assessment
- Scoping Assessment
- Screening Assessment

PHASE II: QUANTITATIVE ASSESSMENT

- Tier II: Site-Specific Ecological Risk Assessment

As discussed above and illustrated in Figure 1, the Scoping Assessment is the first phase of the Tier I Screening-Level Ecological Risk Assessment process as defined by the NMED GAERPC. This document provides specific procedures to assist the facility in conducting the first step (Scoping Assessment) of the Tier I, Screening-Level Ecological Risk Assessment process outlined in the GAERPC. The purpose of the Scoping Assessment is to gather information, which will be used to determine if there is "any reason to believe that ecological receptors and/or complete exposure pathways exist at or in the locality of the site" (NMED, 2000). The scoping assessment step also serves as the initial information-gathering phase for sites clearly in need of a more detailed assessment of potential ecological risk. This document outlines the methodology for conducting a Scoping Assessment, and includes a Site Assessment Checklist (Attachment A), which serves as tool for gathering information about the facility property and surrounding areas. Although the GAERPC provides a copy of the US EPA Checklist for Ecological Assessment/Sampling (US EPA, 1997), the attached Site Assessment Checklist provides an expanded, user-friendly template, which both guides the user as to what information to collect and furnishes an organized structure in which to enter the information.

After the Site Assessment Checklist has been completed, the assessor must use the collected information to generate a Scoping Assessment Report and Preliminary Conceptual Site Exposure Model (PCSEM). Guidance for performing these tasks is provided in this document, and in the GAERPC. The Scoping Assessment Report and PCSEM are subsequently used to address the first in a series of Technical Decision Points of the tiered GAERPC process. Technical Decision Points are questions which must be answered by the assessor after the completion of certain phases in the process. The resulting answer to the question determines the next step to be undertaken by the facility. The first Technical Decision Point, as illustrated in Figure 1, is to decide: *Is Ecological Risk Suspected?*

If the answer to the first Technical Decision Point is "no" (that is, ecological risk is not suspected), the assessor may use the Exclusion Criteria Checklist and Decision Tree (Attachment B) to help confirm or deny that possibility. However, it is unlikely that any site containing potential ecological habitat or receptors will meet the Site Exclusion Criteria.

If ecological risk is suspected, the facility will usually be directed to proceed to the next phase of Tier I, which is a Screening Level Ecological Risk Assessment (SLERA). A SLERA is a simplified risk assessment that can be conducted with limited site-specific data by defining assumptions for parameters that lack site-specific data (US EPA, 1997). Values used for screening are consistently biased in the direction of overestimating risk to ensure that sites that might pose an ecological risk are properly identified. The completed Site Assessment Checklist is a valuable source of information needed for the completion of the SLERA. Instructions for performing a SLERA can be found in the GAERPC and in a number of EPA guidance documents (e.g., US EPA, 1997; US EPA, 1998).

2. Scoping Assessment

The Scoping Assessment serves as the initial information gathering and evaluation phase of the Tier I process. A Scoping Assessment consists of the following steps:

- Compile and Assess Basic Site Information (using Site Assessment Checklist)
- Conduct Site Visit
- Identify Preliminary Contaminants of Potential Ecological Concern
- Develop a Preliminary Conceptual Site Exposure Model
- Prepare a Scoping Assessment Report

The following subsections provide guidance for completing each step of the Scoping Assessment. For additional guidance, readers should refer to the GAERPC (NMED, 2000).

2.1 Compile and Assess Basic Site Information

The first step of the Scoping Assessment process is to compile and assess basic site information. Since the purpose of the Scoping Assessment is to determine if ecological habitats, receptors, and complete exposure pathways are likely to exist at the site, those items are the focus of the information gathering. The Site Assessment Checklist (Attachment A) should be used to complete this step. The questions in the Site Assessment Checklist should be addressed as completely as possible with the information available before conducting a site visit.

In many cases, a large portion of the Site Assessment Checklist can be completed using reference materials and general knowledge of the site. A thorough file search should be conducted to compile all potential reference materials. Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) and Facility Investigation (RFI) reports, inspection reports, RCRA Part B Permit

Applications, and facility maps can all be good sources of the information needed for the Site Assessment Checklist.

Habitats and receptors which may be present at the site can be identified by contacting local and regional natural resource agencies. Habitat types may be determined by reviewing land use and land cover maps (LULC), which are available via the Internet at http://www.nationalatlas.gov/scripts. Additional sources of general information for the identification of ecological receptors and habitats are listed in the introduction section of the Site Assessment Checklist (Attachment A).

After all available information has been compiled and entered into the Site Assessment Checklist, the assessor should review the checklist and identify data gaps. Plans should then be made to obtain the missing information by performing additional research and/or by observation and investigation during the site visit.

2.2 SITE VISIT

When performing a Scoping Assessment, at least one site visit should be conducted to directly assess ecological features and conditions. As discussed in the previous section, completion of the Site Assessment Checklist should have begun during the compilation of basic site information. The site visit allows for verification of the information obtained from the review of references and other information sources. The current land and surface water usage and characteristics at the site can be observed, as well as direct and indirect evidence of receptors. In addition to the site, areas adjacent to the site and all areas where ecological receptors are likely to contact site-related chemicals (i.e., all areas which may have been impacted by the release or migration of chemicals from the site) should be observed or visited and addressed in the Site Assessment Checklist. The focus of the habitat and receptor observations should be on a community level. That is, dominant plant and animal species and habitats (e.g., wetlands, wooded areas) should be identified during the site visit. Photographs should be taken during the site visit and attached to the Scoping Assessment Report. Photographs are particularly useful for documenting the nature, quality, and distribution of vegetation, other ecological features, potential exposure pathways, and any evidence of contamination or impact. While the focus of the survey is on the community level, the U.S. Fish and Wildlife Service and the New Mexico Natural Heritage Program should be contacted prior to the site visit. The intent is to determine if state listed and/or federal listed Threatened & Endangered (T&E) species or sensitive habitats may be present at the site, or if any other fish or wildlife species could occur in the area (as indicated in the Site Assessment Checklist, Section IIID). A trained biologist or ecologist should conduct the biota surveys to appropriately characterize major habitats and to determine whether T&E species are present or may potentially use the site. The site assessment should also include a general survey for T&E species and any sensitive habitats (e.g. wetlands, perennial waters, breeding areas), due to the fact that federal and state databases might not be complete.

Site visits should be conducted at times of the year when ecological features are most apparent (i.e., spring, summer, early fall). Visits during winter might not provide as much evidence of the presence or absence of receptors and potential exposure pathways.

In addition to observations of ecological features, the assessor should note any evidence of chemical releases (including visual and olfactory clues), drainage patterns, areas with apparent erosion, signs of groundwater discharge at the surface (such as seeps or springs), and any natural or anthropogenic site disturbances.

2.3 Identify Contaminants of Potential Ecological Concern

Contaminants of Potential Ecological Concern (COPECs) are chemicals which may pose a threat to individual species or biological communities. For the purposes of the Scoping Assessment, all chemicals known or suspected of being released at the site are considered COPECs. The identification of COPECs is usually accomplished by the review of historical information in which previous site activities and releases are identified, or by sampling data which confirm the presence of contaminants in environmental media at the site. If any non-chemical stressors such as mechanical disturbances or extreme temperature conditions are known to be present at the site, they too are to be considered in the assessment.

After the COPECs have been identified, they should be summarized and organized (such as in table or chart form) for presentation in the Scoping Assessment Report.

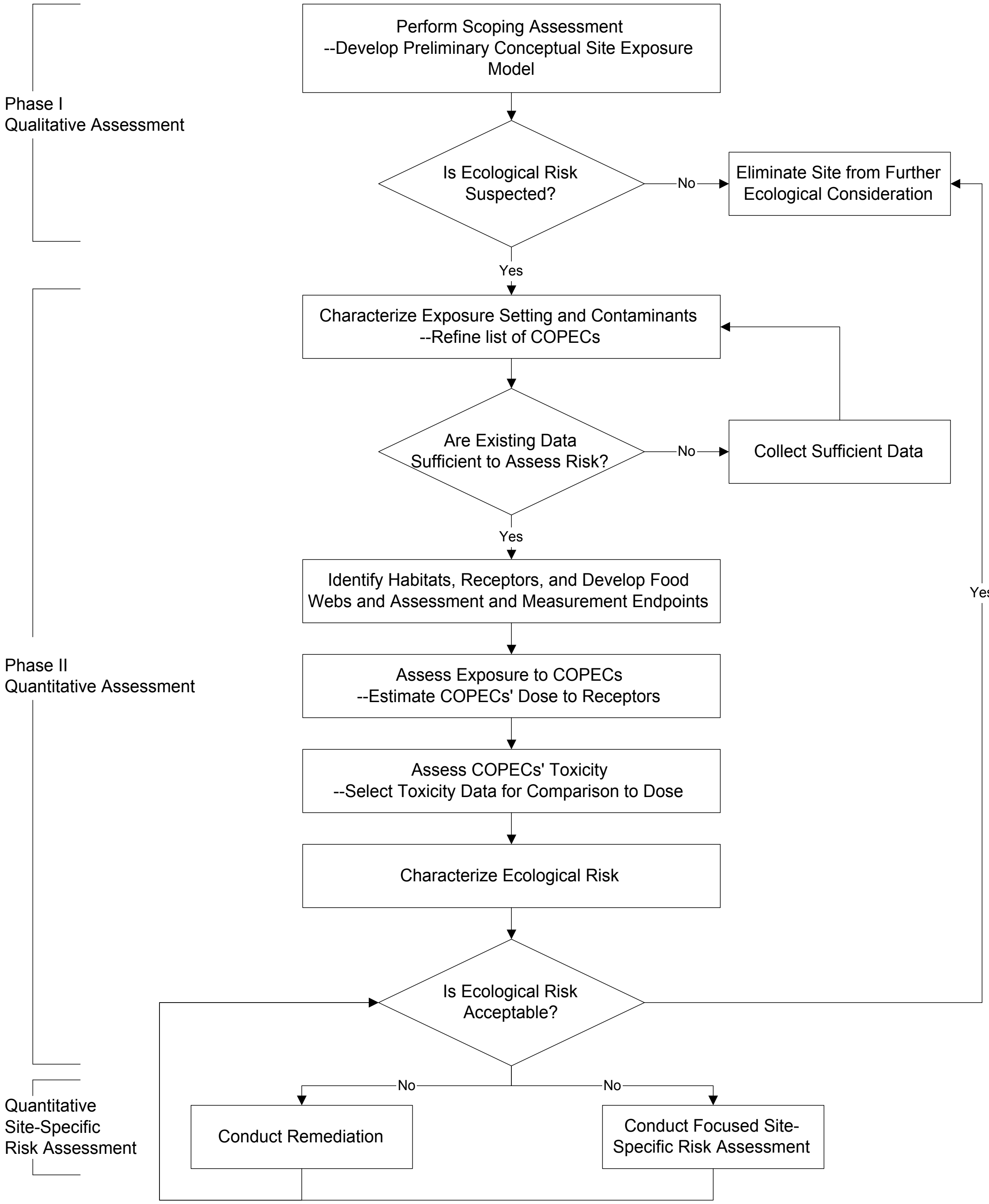
2.4 Developing the Preliminary Conceptual Site Exposure Model

A PCSEM provides a summary of potentially complete exposure pathways, along with potentially exposed receptor types. The PCSEM, in conjunction with the scoping report, is used to determine whether further ecological assessment (i.e., Screening-Level Assessment, Site-Specific Assessment) and/or interim measures are required.

A complete exposure pathway is defined as a pathway having all of the following attributes (US EPA, 1998; NMED, 2000):

- A source and mechanism for hazardous waste/constituent release to the environment
- An environmental transport medium or mechanism by which a receptor can come into contact with the hazardous waste/constituent
- A point of receptor contact with the contaminated media or via the food web, and
- An exposure route to the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site. A discussion regarding all possible exposure pathways and the rationale/justification for eliminating any pathways should be included in the PCSEM narrative and in the Scoping Assessment Report.



Adapted from GAERPC (NMED 2000).

Figure 1. NMED Ecological Risk Assessment Process

The PCSEM is presented as both a narrative discussion and a diagram illustrating potential contaminant migration and exposure pathways to ecological receptors. A sample PCSEM diagram is presented in Figure 2. On the PCSEM diagram, the components of a complete exposure pathway are grouped into three main categories: sources, release mechanisms, and potential receptors. As a contaminant migrates and/or is transformed in the environment, sources and release mechanisms can be defined as primary, secondary, and tertiary.

For example, Figure 2 depicts releases from a landfill that migrate into soils, and reach nearby surface water and sediment via storm water runoff. In this situation, the release from the landfill is considered the primary release, with infiltration as the primary release mechanism. Soil becomes the secondary source, and storm water runoff is the secondary release mechanism to surface water and sediments, the tertiary source.

Subsequent ecological exposures to terrestrial and aquatic receptors will result from this release. The primary exposure routes to ecological receptors are direct contact, ingestion, and possibly inhalation. For example, plant roots will be in direct contact with contaminated sediments, and burrowing mammals will be exposed via dermal contact with soil and incidental ingestion of contaminated soil. In addition, exposures for birds and mammals will occur as they ingest prey items through the food web.

Although completing the Site Assessment Checklist will not provide the user with a ready made PCSEM, a majority of the components of the PCSEM can be found in the information provided by the Site Assessment Checklist. The information gathered for the completion of Section II of the Site Assessment Checklist, can be used to identify sources of releases. The results of Section III, Habitat Evaluation, can be used to both identify secondary and tertiary sources and to identify the types of receptors which may be exposed. The information gathered for completion of Section IV, Exposure Pathway Evaluation, will assist users in tracing the migration pathways of releases in the environment, thus helping to identify release mechanisms and sources.

Once all of the components of the conceptual model have been identified, complete exposure pathways and receptors that have the potential for exposure to site releases can be identified.

For further guidance on constructing a PCSEM, consult the GAERPC (NMED, 2000), and EPA's Office of Solid Waste and Emergency Response's *Soil Screening Guidance: User's Guide* (1996).

2.5 ASSEMBLING THE SCOPING ASSESSMENT REPORT

After completion of the previously described activities of the scoping assessment, the Scoping Assessment Report should be assembled to summarize the site information and present an evaluation of receptors and pathways at the site. The Scoping Assessment Report should be designed to support the decision made regarding the first Technical Decision Point (Is Ecological Risk Suspected?). The Scoping Assessment Report should, at a minimum, contain the following information:

- Existing Data Summary
- Site Visit Summary (including a completed Site Assessment Checklist)

- Evaluation of Receptors and Pathways
- Recommendations
- Attachments (e.g. photographs, field notes, telephone conversation logs with natural resource agencies)
- References/Data Sources

After completion, the Scoping Assessment Report and PCSEM should be submitted to NMED for review and approval. These documents will serve as a basis for decisions regarding future actions at the site.

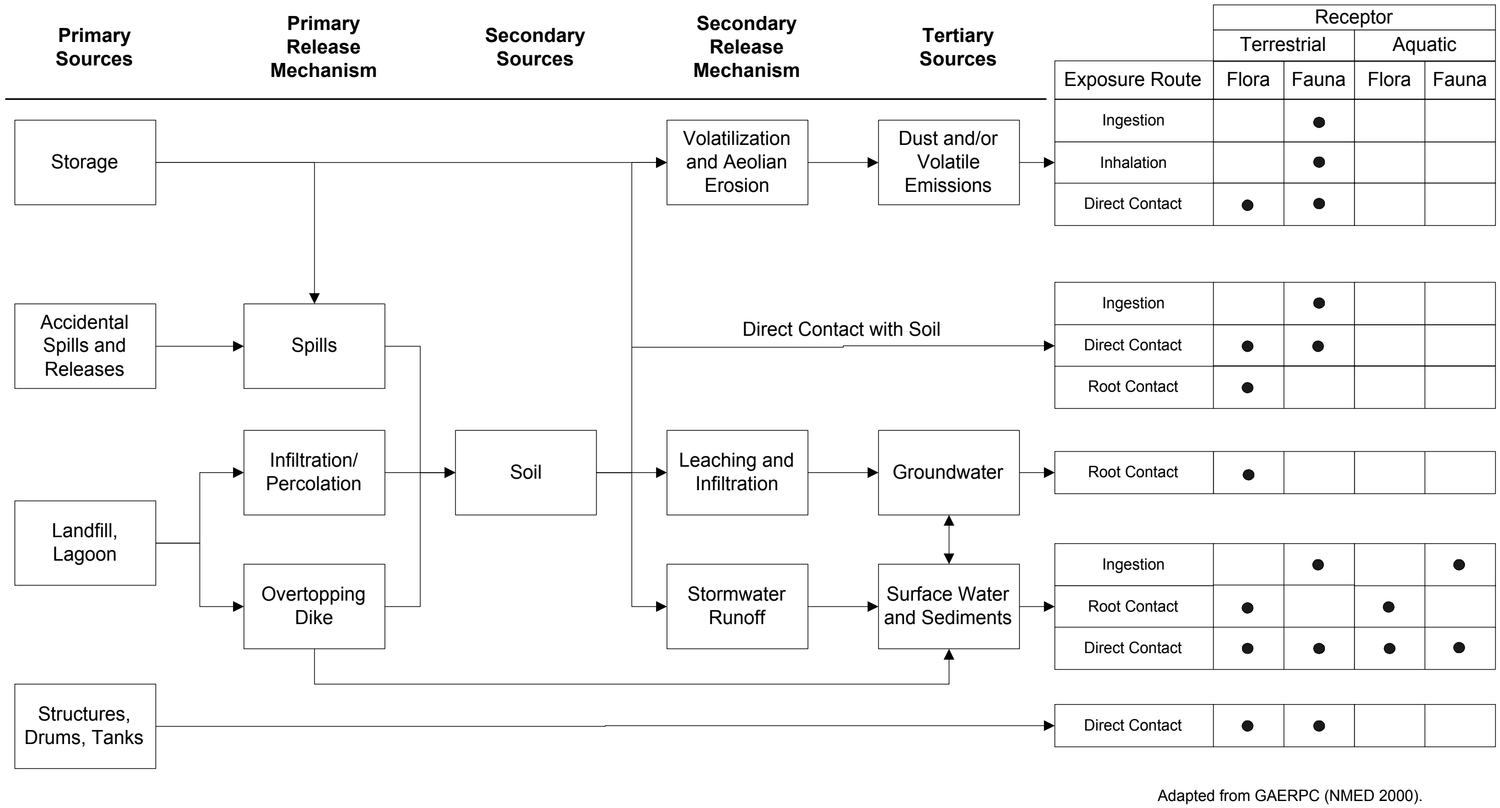


Figure 2. Example Preliminary Conceptual Site Exposure Model Diagram for a Hypothetical Site

3. Site Exclusion Criteria

If the assessor believes that the answer to the first Technical Decision Point (Is Ecological Risk Suspected?) is "no" based on the results of the PCSEM and Scoping Assessment Report, it should be determined whether the facility meets the NMED Site Exclusion Criteria.

Exclusion criteria are defined as those conditions at an affected property which eliminate the need for a SLERA. The three criteria are as follows:

- Affected property does not include viable ecological habitat.
- Affected property is not utilized by potential receptors.
- Complete or potentially complete exposure pathways do not exist due to affected property setting or conditions of affected property media.

The Exclusion Criteria Checklist and associated Decision Tree (Attachment B) can be used as a tool to help the user determine if an affected site meets the exclusion criteria. The checklist assists in making a conservative, qualitative determination of whether viable habitats, ecological receptors, and/or complete exposure pathways exist at or in the locality of the site where a release of hazardous waste/constituents has occurred. Thus, meeting the exclusion criteria means that the facility can answer "no" to the first Technical Decision Point.

If the affected property meets the Site Exclusion Criteria, based on the results of the checklist and decision tree, the facility must still submit a Scoping Assessment Report to NMED which documents the site conditions and justification for how the criteria have been met. Upon review and approval of the exclusion by the appropriate NMED Bureau, the facility will not be required to conduct any further evaluation of ecological risk. However, the exclusion is not permanent; a future change in circumstances may result in the affected property no longer meeting the exclusion criteria.

4. Technical Decision Point: Is Ecological Risk Suspected?

As discussed in the beginning of this document, the Scoping Assessment is the first phase of the GAERPC ecological risk assessment process (Figure 1). Following the submission of the Scoping Assessment Report and PCSEM, NMED will decide upon one of the following three recommendations for the site:

- No further ecological investigation at the site, or
- Continue the risk assessment process, and/or
- Undertake a removal or remedial action.

If the information presented in the Scoping Assessment Report supports the answer of "no" to the first Technical Decision Point, and the site meets the exclusion criteria, the site will likely be excused from further consideration of ecological risk. However, this is only true if it can be documented that a complete exposure pathway does not exist and will not exist in the future at the site based on current conditions. For those sites where valid pathways for potential exposure exist or are likely to exist in the future, further ecological risk assessment (usually in the form of a SLERA) will be required. However, if the Scoping Assessment indicates that a detailed assessment is warranted, the facility would not be required to conduct a SLERA. Instead the facility would move directly to Tier II–Site-Specific Ecological Risk Assessment.

References

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